PATENT

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant: Nguyen Xuan Nguyen et al.	Group Art No.: 2815
Application No: 10/600,521	Examiner: Brock II, Paul E
Filed: June 19, 2003	Re: **RESPONSE**
For: "A PROCESS FOR FABRICATING . . . "	Our Ref: B-3863NP 620845-2/RPB
	Date: November 22, 2004

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

DECLARATION OF PRIOR INVENTION IN THE UNITED STATES TO OVERCOME CITED PATENT OR PUBLICATION (37 CFR 1.131)

1. This declaration is to establish completion of the invention in this application in the United States, at a date prior to June 28, 2001, which is the filing date of United States Patent 6,492,669 to Nakayama.

2. The persons making this declaration are the inventors.

FACTS AND DOCUMENTARY EVIDENCE

3. To establish the date of completion of the invention of this application, the following attached documents are submitted as evidence:

- invention disclosure document
- copies of laboratory notes of the inventors

- statements by the inventors presented herein.

4. The attached invention disclosure document is a true and correct copy of the invention disclosure document completed and signed by each named inventor.

5. The attached invention disclosure document, dated December 22, 1999 and signed by the inventors on December 20, 1999 shows, in section 4 of sheet 2 ("Reduction to Practice") that the present invention was reduced to practice between June 1999 and July 1999. The above time interval is prior to the June 28, 2001 filing date of U.S. Pat. No. 6,492, 669 to Nakayama cited by the USPTO Examiner in the Official Action of June 22, 2004.

6. Evidence of reduction to practice of the invention by July 1999 is also presented, with reference to copies of laboratory notes of the inventors enclosed with the present declaration. Those pages are notes from 1999 taken from the inventors' notebooks with reference to the invention at issue. Those pages are additional evidence that the invention was reduced to practice in June-July 1999, prior to the June 28, 2001 filing date of Nakayama. A subset of the enclosed pages (i.e. pages 1-22) will be commented in detail below.

7. The inventors submit that all claims 1-32 as filed, and thus currently pending process claims 1-16, are directed to inventions that were reduced to practice by July 1999, prior to the June 28, 2001 filing date of Nakayama.

8. A list of currently pending process claims 1-16 is presented in the response to the Action of June 22, 2004 accompanying the present declaration.

9. We submit that a process in accordance with the recitation of claim 1 was reduced to practice by July 1999. With reference to the enclosed notebook papers, the following should be noted:

a) Claim 1 recites a process for fabricating ohmic contacts in a field-effect transistor. Pages 1-5 of the enclosed laboratory notes show an "Ohmic P/R Process" and a "Wafer ID." Pages 6 and 7 of the enclosed laboratory notes recite (top right) a "GaN process." Pages 1-5 of the enclosed laboratory notes refer to processes performed starting on May 10, 1999, June 21, 1999, June 25, 1999, July 8, 1999 and July 13, 1999, respectively. Pages 6 and 7 of the enclosed laboratory notes refer to processes performed between January and February 1999, as also indicated on page 8 of the enclosed laboratory notes .

b) Claim 1 further recites that the process includes a step of thinning the first semiconductor layer forming recessed portions in the semiconductor layer. Pages 9-11 and 13 of the enclosed laboratory notes show an "ohmic recess etch" steps performed on different lots. Note that page 9 of the enclosed laboratory notes recites "ohmic etch 5-14-1999" page 10 of the enclosed laboratory notes recites "ohmic recessed 6-22-99", page 11 of the enclosed laboratory notes recites "ohmic etch 6-30-99", page 12 of the enclosed laboratory notes recites "ohmic etch 7-12-99" . Page 14 of the enclosed laboratory notes shows a step # 10 "Ohmic Recess Etch." The same step is also partially shown in Page 8of the enclosed laboratory notes. The processes performed at pages 6, 14 and 7, 8 of the enclosed laboratory notes have January-February 1999 dates.

Page 15 of the enclosed laboratory notes shows additional experimental data about the etching step. Page 16 of the enclosed laboratory notes shows a diagram relating to etching and data about etching conditions. Page 17 of the enclosed laboratory notes shows comparative diagrams between etching and no etching. Page 18 of the enclosed laboratory notes shows diagrams related to different etching depths.

c) Claim 1 further recites depositing ohmic contacts over the recessed portions. Pages 9-11 and 13 of the enclosed laboratory notes show an "Ohmic metal" step, also specified in page 13 of the enclosed laboratory notes as "Ohmic metal evap."

Page 14 (step # 12) of the enclosed laboratory notes shows an "Ohmic Metallization" step. Pages 9-11 and 13 of the enclosed laboratory notes also show June-July 1999 dates. Page 14 of the enclosed laboratory notes shows January-February 1999 dates.

d) Claim 1 further recites heating the deposited ohmic contacts, whereby, after the heating step, the ohmic contacts communicate with the electron gas. Pages 9-11 and 13 of the enclosed laboratory notes show an "RTA Anneal" step. See also the handwritten notes at page 12 of the enclosed laboratory notes and the last handwritten note at page 13 ("Anneal") of the enclosed laboratory notes .

10. We also submit that a process in accordance with the recitation of claim 2-16 was reduced to practice by July 1999. For example:

a) With reference to claim 2, some of the enclosed pages make reference to GaN semiconductors. See, for example, the top portion of pages 6, 14, 7 and 8 of the enclosed laboratory notes .

b) With reference to claims 3 and 15, some of the enclosed pages make reference to Ti-Al-Ni Au ohmic contacts. See, for example, pages 9-13 of the enclosed laboratory notes .

c) With reference to claim 5, most of the enclosed pages make reference to a reactive ion etching (RIE) process. See, for example, pages 9-13 of the enclosed laboratory notes .

d) With reference to claim 6, most of the enclosed pages make reference to a process employing chlorine (Cl_2). See, for example, pages 9-13 of the enclosed laboratory notes .

e) With reference to claim 7, page 16 of the enclosed laboratory notes represents a diagram with a linear etching function.

f) With reference to claim 11, pages 9-11 and 13 of the enclosed laboratory notes make reference to a heating step performed at 875 ° C.

g) With reference to claim 13, pages 9-11 and 13 of the enclosed laboratory notes make reference to a thinning step performed up to 200 Angstrom.

11. Additional evidence is also shown by the photographs at pages 19-22 of the enclosed laboratory notes. Those photographs are additional evidence not only that a process was performed, but also that a device was built.

12. Additional pages from the inventor's notebooks, not expressly highlighted in the comments above are submitted with the present response. Although these pages have not been commented in detail, they are deemed to be relevant, as additional evidence showing that the invention as claimed in claims 1-16 was reduced to practice.

13. We submit that Nakayama does not claim the same patentable invention of the present application.

14. This declaration is submitted prior to final rejection.

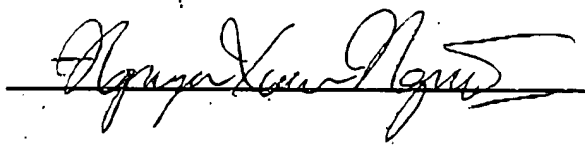
15. As one of the inventors signing below:

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like are so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

SIGNATURES

Inventors:

Full name of first inventor: Nguyen Xuan Nguyen

Inventor's Signature:  Date 11/22/2004

Full name of second inventor: Paul Hashimoto

Inventor's Signature: _____ Date

Full name of third inventor: Chanh Nguyen

Inventor's Signature: _____ Date

15. As one of the inventors signing below:

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like are so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

SIGNATURES

Inventors:

Full name of first inventor: Nguyen Xuan Nguyen

Inventor's Signature: _____ Date

Full name of second inventor: Paul Hashimoto

Inventor's Signature: Paul Hashimoto 19 NOV 2004 Date

Full name of third inventor: Chanh Nguyen

Inventor's Signature: _____ Date

PATENT

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

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DECLARATION OF UNAVAILABILITY OF INVENTOR

1. My name is Mel Kyle

2. I work for HRL Laboratories, LLC ("HRL") as a paralegal.

3. HRL is the assignee of U.S. Pat. App. 10/600,521 filed on June 19, 2003 and directed to "A process for fabricating ultra-low contact resistances in GaN-based devices."

4. Mr. Chanh Nguyen, one of the inventors of the above application, is no longer an employee of HRL.

5. With reference to the Declaration of Prior Invention under 37 CFR 1.131 to be filed for the above application, I have tried to locate Mr. Chanh Nguyen. According to the last information HRL had on him, Mr. Chanh Nguyen was living at the address listed in the declaration he signed with reference to the present application and was working at GCS located at 23155 Kashiwa Court, Torrance, CA 90505.

6. I tried contacting Mr. Chanh Nguyen regarding the above application and called him at GCS ((310) 530-7274) and learned that he is no longer with GCS.

7. Other people at HRL made phone calls trying to locate Mr. Chanh Nguyen. I have been informed by those people that apparently Mr. Chanh Nguyen is currently in Paris, France taking some time off before he begins a new job, and cannot be reached.

8. Therefore, Mr. Chanh Nguyen is currently unavailable.

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like are so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Full name: Mel Kyle

Signature: Mel Kyle

Date: 11-19-04

GaN MMD low pressure

GaN **Ohmic P/R Process (using 365nm filter on Ch 1)** Date 5-10-99
Wafer ID: 376, 376 (Flat), 379, 379 (flat)
Danny Wong Version 1 **April 12, 1999** **HRL PROPRIETARY**

5-10-99 pk Make Al foil for edge bead flood expose.

5-10-99 pk ACE rinse 30 sec., IPA rinse 30 sec., DI rinse 60 sec., blow dry.

10 pk Drying bake – 100C, 1 min., vac hot plate.

10 pk Spin on AZ 5214EIR, 3500 rpm, 30 sec. (~1.4 um)

10 pk Dehydration bake – 100C, 1 min., vac hot plate.

10 pk Edge bead removal – flood expose edge for ~~20~~ 10 sec (clear wafers) @ 20mW/sq.cm., develop 30 sec. in 1:5=351:DI, DI rinse 1 min., blow dry, examine for edge bead removal. 376F No tape

376
376 Flat
379
379 Flat

- Insert the 365nm band pass filter into the only open slot inside the optics train in front of the lamp housing. On KSA #1 aligner's power supply, switch to Channel 1. Calibrate the intensity in mW/sq.cm. using the handheld OAI meter with the 365nm sensor. The in-control is set at 5.0 mW/sq.cm.

  Note: after usage, remove filter, switch back to Channel 2 and check in-control intensity is at 20.0 mW/sq.cm.

- Image align & expose: ensure proper contact rainbow fringes on sample.
  Record contact setting _____
  Use soft contact, align with Power 1 Ohmic mask. Use Channel 1 set up previously.
  Expose for ~~16~~ sec (~~80~~ mJ/sq.cm.) typical for clear sample. 75mJ ~~70mJ~~ 15 sec
  Record expose time 376HF ~70mJ, 110, 155 → side wall straight – SEM CD = 2.1, 2.3

10 pk Post Expose Bake (PEB): on vac hot plate, 100C, 1 min. 10 sec. typical.
Flood expose: on KSA aligner, 1 min. at 20 mW/sq.cm.

10 pk Develop in 1:5=351:DI for 20 sec. typical. DI rinse 2 min., blow dry.
Record develop time _____
Inspect under microscope for rainbow P/R residue inside patterns, take photos.
If needed, additional 5 sec develop, DI rinse 2 min. and blow dry.
Record additional develop time _____

10 pk Take optical microscope photos of CD pattern at different locations. Take SEM photos for straight sidewall profile and 2.0 um S/D spacings at same location areas.

pk LF5 O2 plasma clean: 100W, 2 min., 200mT. Run 446

Ohmic P/R process Version 1 continue

5/4 NxN **Ohmic recess etch: use Cl2 RIE at UCSB. Target ~200A based on test samples at 400A/min rate.**

5/4 NxN **Just prior to sample loading for ohmic metal: 15:1 DI diluted NH4OH for 30 sec dip, DI rinse 1 min., blow dry.**

5-11 NxN **Ohmic metal: use Bay 1 evaporator to deposit Ti-Al-Ni-Au 200-2000-400-500A.**

5-14, PL **Lify off: ACE soak 15 min. Ultrasonic ACE 1 min. ACE spray 15 sec., clean in ACE 30 sec., IPA clean 30 sec., DI rinse 60 sec., blow dry. Examine for metal residue. Take photos.**

(+) 376 NF - much residue @ Ghost of PR pattern of prior ohmic no stripped off completely

- **RTA Anneal at 875C, 30 sec.**
- **Check I-V for 2um S/D spacing on curve tracer.**

ohmic etch

5-14-1999

Ohmic P/R Process (using 365nm filter on Ch 1) | Lot 12 | Date 6/21/99

Wafer ID: 393, ~~394~~, 396, 398

Danny Wong Version 1 April 12, 1999 ERL PROPRIETARY

~~394~~ 404 recess gate

6/21 * For 396/398, deposit 100A SiN before Ohmic P/R process

*396 SiN 100A before Ohmic P/R process

*398 SiN 100A before Ohmic P/R process

6/21 Make Al foil for edge bead flood expose.

LOT 12

6/21 ACE rinse 30 sec., IPA rinse 30 sec., DI rinse 60 sec., blow dry.

6/22 - Drying bake – 100C, 1 min., vac hot plate.

6/22 * 100% HMDS : spin at 3500 rpm, 30 sec for 396/398 samples (then AZ 5214 P/R)

6/22 Spin on AZ 5214EIR, 3500 rpm, 30 sec. (~1.4 um)

393 only

6/22 Dehydration bake – 100C, 1 min., vac hot plate. for clear wfr, 70°C, 1 min for opaque wfrs

6/22 Edge bead removal – flood expose edge for ~~20~~ 10 sec @ 20mW/sq.cm., for clear, 5 sec for Opaque develop 30 sec. in 1:5=351:DI, DI rinse 1 min., blow dry, examine for edge bead removal.

6/22 Insert the 365nm band pass filter into the only open slot inside the optics train in front of the lamp housing. On KSA #1 aligner's power supply, switch to Channel 1. Calibrate the intensity in mW/sq.cm. using the handheld OAI meter with the 365nm sensor. The in-control is set at 5.0 mW/sq.cm.

Note: after usage, remove filter, switch back to Channel 2 and check in-control intensity is at 20.0 mW/sq.cm.

6/22 NKN - Image align & expose: ensure proper contact rainbow fringes on sample.
Record contact setting _____
Use soft contact, align with Power 1 Ohmic mask. Use Channel 1 set up previously.
Expose for ~~16~~ 12 sec (~~80~~ mJ/sq.cm.) typical for clear sample. 9sec (45mJ) for Opaque.
Record expose time 60 _____

6/22 NKN - Post Expose Bake (PEB): on vac hot plate, 100C, 1 min. 10 sec. typical. clear [55 sec for opaque]
Flood expose: on KSA aligner, 1 min. at 20 mW/sq.cm.

6/22 NKN - Develop in 1:5=351:DI for ~~20~~ 15 sec. typical. DI rinse 2 min., blow dry.
Record develop time _____
Inspect under microscope for rainbow P/R residue inside patterns, take photos.
If needed, additional 5 sec develop, DI rinse 2 min. and blow dry.
Record additional develop time _____

PAGE 2

- Take optical microscope photos of CD pattern at different locations. Take SEM photos for straight sidewall profile and ~~2.0~~ 1.9 um S/D spacings at same location areas.

6/22 LF5 O2 plasma clean: 100W, 2 min., 200mT. only on 396, 398 Run 1313

6/22 100A SiN etch: CF4/O2 RIE in ~~plasma therm~~ semi-group
for 396/398 samples BOE dip ~~3~~ (5 sec, DI 2 min, blow dry

6/22 All 4 samples → LCSP @ C1 RIE

Lot #12

Ohmic P/R process Version 1 continue

6/22 NKN - Ohmic recess etch: use Cl2 RIE at UCSB. Target ~200A based on test samples at 400A/min rate.

- Just prior to sample loading for ohmic metal: 15:1 DI diluted NH_4OH for 30 sec dip, DI rinse 1 min., blow dry. W/18

- Ohmic metal: ~~use Bay 4~~ CHA evaporator to deposit Ti-Al-Ni-Au 200-2000-400-500A.

~~[illegible]~~

6/22 pk - Lift off: ACE soak 15 min. Ultrasonic ACE 1 min. ACE spray 15 sec., clean in ACE 30 sec., IPA clean 30 sec., DI rinse 60 sec., blow dry. Examine for metal residue. Take photos.

~~[illegible] 393 Liftoff + PRS + scrub - dirty residue [illegible]~~

6/23 NKN - RTA Anneal at 875C, 30 sec.

6/25 NKN - Check I-V for 2um S/D spacing on curve tracer.

PAGE 10

Ohmic Lift off inspection
393 = ok
396 = many particles some in S-D
398 = Many 2um lifted S-D resist
almost all 20 gated devices = lifted

404 - 5048 95 residue in gate
3049 :94 " " "
Most residue is NOT in S-D area

6/24-99 pk inspect

6/24/99 PRS 1000 100°C 60' scrub + 5'
∴ resist removed!!!

Beaker process

Lot 12 start 6-21-99
Ohmic recessed 6-22-99

PD 9232AL

Ohmic P/R Process (using 365nm filter on Ch 1) **Date** 6-25-99

Wafer ID: GaN: 408, 408, 409, 409

Danny Wong Version 1 April 12, 1999 **HRL PROPRIETARY**

LOT 13

Start 6-25-99 fri

6/25 ph Make Al foil for edge bead flood expose.

6/25 pm – PRS1000 50°C @ 15 min, swabs, + 5' PRS → H2O rnse (All 4 wfrs)

6/28 ph ACE rinse 30 sec., IPA rinse 30 sec., DI rinse 60 sec., blow dry.

6/28 ph Drying bake – 100C, 1 min., vac hot plate.

6/28 ph Spin on AZ 5214EIR, 3500 rpm, 30 sec. (~1.4 um)

6/28 ph Dehydration bake – 100C, 1 min., vac hot plate. for clear wfr. 70°C, 1 min for opaque wfrs

6/28 pL Edge bead removal – flood expose edge for ~~20~~ 10 sec @ 20mW/sq.cm., for clear, 5 sec for Opaque
develop 30 sec. in 1:5=351:DI, DI rinse 1 min., blow dry,
examine for edge bead removal.

Lot 13
#409
Completed
Part of
Span

6/24 NKH Insert the 365nm band pass filter into the only open slot inside the optics train in front of the lamp housing. On KSA #1 aligner's power supply, switch to Channel 1. Calibrate the intensity in mW/sq.cm. using the handheld OAI meter with the 365nm sensor. The in-control is set at 5.0 mW/sq.cm.

Note: after usage, remove filter, switch back to Channel 2 and check in-control intensity is at 20.0 mW/sq.cm.

- Image align & expose: ensure proper contact rainbow fringes on sample.
  Record contact setting _____
  Use soft contact, align with Power 1 Ohmic mask. Use Channel 1 set up previously.
  Expose for ~~16~~ 12 sec (~~80~~ 60 mJ/sq.cm.) typical for clear sample. 9sec (45mJ) for Opaque.
  Record exposure time _____

- Post Expose Bake (PEB): on vac hot plate, 100C, 1 min. 10 sec. typical. clear. 55sec for opaque
  Flood expose: on KSA aligner, 1 min. at 20 mW/sq.cm.

- Develop in 1:5=351:DI for ~~20~~ 15 sec. typical. DI rinse 2 min., blow dry.
  Record develop time _____
  Inspect under microscope for rainbow P/R residue inside patterns, take photos.
  If needed, additional 5 sec develop, DI rinse 2 min. and blow dry.
  Record additional develop time _____

- Take optical microscope photos of CD pattern at different locations. Take SEM photos for straight sidewall profile and ~~2.0~~ 1.0 um S/D spacings at same location areas.

6/24/ ph LF5 O2 plasma clean: 100W, 2 min., 200mT.

6/30/ ph – RCA for cl etch

PAGE 3

1 of 13

Ohmic P/R process Version 1 continue

6/30 Ohmic recess etch: use Cl2 RIE at UCSB. Target ~200A based on test samples at 400A/min rate.

- Just prior to sample loading for ohmic metal: 15:1 DI diluted NH_4OH for 30 sec dip, DI rinse 1 min., blow dry.

7/1 NCP Ohmic metal: use Bay 4 evaporator to deposit Ti-Al-Ni-Au 200-2000-400-500A.

7/1 after Lift off: ACE soak 15 min. Ultrasonic ACE 1 min. ACE spray 15 sec., clean in ACE 30 sec., IPA clean 30 sec., DI rinse 60 sec., blow dry. Examine for metal residue. Take photos.

7/1 NCP RTA Anneal at 875C, 30 sec.

- Check I-V for 2um S/D spacing on curve tracer.

7/1 Some gate Flat - PR residue in well S-D very clean
All 9 have PR residue in S-D

7/1 Beaker process PRS 1000 100°C
10' g scrub + 5', Rinse H_2O, IPA, Aceton, IPA

Ohmic etch 6-30-99

Ohmic P/R Process (using 365nm filter on Ch 1) ← mesa etch ico Date 7-8-99
Wafer ID: GaN hostwt 4 14, GaN 4 14 nf = mina flat
Danny Wong Version 1 April 12, 1999 HRL PROPRIETARY

LOT#
SiC 14
① GaN mesa
② GaN mina flat

7-8-99 ph Make Al foil for edge bead flood expose.
7-8-99 PRS1000 50°C pre clean 15 + swab + 5, then rinse

7/8 ph ACE rinse 30 sec., IPA rinse 30 sec., DI rinse 60 sec., blow dry.

7/8 ph Drying bake – 100C, 1 min., vac hot plate.

7/8 ph Spin on AZ 5214EIR, 3500 rpm, 30 sec. (~1.4 um)

7/8 ph Dehydration bake – 100C, 1 min., vac hot plate. for clear wfr, 70°C, 1 min for opaque wfrs

7/8 ph Edge bead removal – flood expose edge for ~~20~~ 10 sec @ 20mW/sq.cm., for clear, 5 sec for Opaque
develop 30 sec. in 1:5=351:DI, DI rinse 1 min., blow dry,
examine for edge bead removal.

7/8 ph 414 NF = 570 contact
Insert the 365nm band pass filter into the only open slot inside the optics train in front of the lamp housing. On KSA #1 aligner's power supply, switch to Channel 1. Calibrate the intensity in mW/sq.cm. using the handheld OAI meter with the 365nm sensor. The in-control is set at 5.0 mW/sq.cm.

Lot 14
414
Complete for Post Span

Note: after usage, remove filter, switch back to Channel 2 and check in-control intensity is at 20.0 mW/sq.cm.

7/8 ph Image align & expose: ensure proper contact rainbow fringes on sample.
Record contact setting 570, 560
Use soft contact, align with Power 1 Ohmic mask. Use Channel 1 set up previously.
Expose for ~~16~~ 12 sec (~~80~~ mJ/sq.cm.) typical for clear sample. 9sec (45mJ) for Opaque.
Record expose time 60

7/8 ph Post Expose Bake (PEB): on vac hot plate, 100C, 1 min. 10 sec. typical. clear. 55sec for opaque
Flood expose: on KSA aligner, 1 min. at 20 mW/sq.cm.

8 ph Develop in 1:5=351:DI for ~~20~~ 15 sec. typical. DI rinse 2 min., blow dry.
Record develop time
Inspect under microscope for rainbow P/R residue inside patterns, take photos.
If needed, additional 5 sec develop, DI rinse 2 min. and blow dry.
Record additional develop time

PAGE 4

8 ph Take optical microscope photos of CD pattern at different locations. Take SEM photos for straight sidewall profile and 2.0 ~~um~~ 1.9 S/D spacings at same location areas.

8 ph LF5 O2 plasma clean: 100W, 2 min., 200mT. Run # 1463

13 pages

7-12-99 ph - Both wafers back from UCSB Cl⁻ RIE
CHA not available till 7/13/99 1:00 PM

7/ - CHA evap. Ti, Al, Ni Au

7/ - Lift off Acetone 15' + Spray + 5-10', IPA

7- - In spec't

7- - Anneal ohmics

Ohmics etch 7-12-99 ?

Ohmic P/R Process (using 365nm filter on Ch 1) + GaN 419 No Flat Date 7-13-99
Wafer ID: GaN 415 NF, GaN 415 F, WT 990409A1 (½ wafer)
Danny Wong Version 1 **April 12, 1999** **HRL PROPRIETARY**

7-13 dw Make Al foil for edge bead flood expose.

7-13 dw ACE rinse 30 sec., IPA rinse 30 sec., DI rinse 60 sec., blow dry.

7-13 dw Drying bake – 100C, 1 min., vac hot plate.

7-13 dw Spin on AZ 5214EIR, 3500 rpm, 30 sec. (~1.4 um)

7/13 dw Dehydration bake – 100C, 1 min., vac hot plate.

7-13 dw Edge bead removal – flood expose edge for ~~20~~ 10 sec @ 20mW/sq.cm., develop 30 sec. in 1:5=351:DI, DI rinse 1 min., blow dry, examine for edge bead removal.

13-dw Insert the 365nm band pass filter into the only open slot inside the optics train in front of the lamp housing. On KSA #1 aligner's power supply, switch to Channel 1. Calibrate the intensity in mW/sq.cm using the handheld OAI meter with the 365nm sensor. The in-control is set at 5.0 mW/sq.cm.

Note: after usage, remove filter, switch back to Channel 2 and check in-control intensity is at 20.0 mW/sq.cm.

13 dw Image align & expose: ensure proper contact rainbow fringes on sample.
Record contact setting _____
Use soft contact, align with Power 1 Ohmic mask. Use Channel 1 set up previously.
Expose for ~~16~~ 12 sec (~~20~~ mJ/sq.cm.) typical for clear sample.
Record expose time 60

13 dw Post Expose Bake (PEB): on vac hot plate, 100C, 1 min. 10 sec. typical.
Flood expose: on KSA aligner, 1 min. at 20 mW/sq.cm.

13 dw Develop in 1:5=351:DI for ~~20~~ 15 sec. typical. DI rinse 2 min., blow dry.
Record develop time _____
Inspect under microscope for rainbow P/R residue inside patterns, take photos.
If needed, additional 5 sec develop, DI rinse 2 min. and blow dry.
Record additional develop time _____

3 dw Take optical microscope photos of CD pattern at different locations. Take SEM photos for straight sidewall profile and 2.0 um S/D spacings at same location areas.

dw LF5 O2 plasma clean: 100W, 2 min., 200mT.

PAGES

WT = 95% of 2 um = lifted a ~~to~~ sheet → strip on 7/14
WT: 2nd time = also poor adhesion
WT: 3rd time strip poor adhesion
2 wafers 415F Run 1507 100W, 2'
1/99 dw WT 990409A1 & GaN 419 No Flat & Both Ohmic PR spun + exposed successfully NXN (Ohmic 4th time) PR
Dehydration Bake = 1'+1'+2'
1/21/99 dw LF5 Run 1576 2' 100W
2/99 NXN - Ohmic PR, Expose on GaN 420 = Done

415F 65mJ 1'13'
415NF 55mJ 1'10'
WT 45 55'
PEB
9sec (45mJ) for Opaque.
55sec for opaque

Ohmic P/R process Version 1 continue

7-14 NXN - Ohmic recess etch: use Cl2 RIE at UCSB. Target ~200A based on test samples at 400A/min rate.

- Just prior to sample loading for ohmic metal: 15:1 DI diluted NH_4OH for 30 sec dip, DI rinse 1 min., blow dry.

Lot 15

1/ NXN Ohmic metal: use Bay 4 evaporator to deposit Ti-Al-Ni-Au 200-2000-400-500A.

1/14 Lift off: ACE soak 15 min. Ultrasonic ACE 1 min. ACE spray 15 sec., clean in ACE 30 sec., IPA clean 30 sec., DI rinse 60 sec., blow dry. Examine for metal residue. Take photos. 415 Flat cracked → Sot
415 Both are much!! residue on ohmic

1/14/99 NXN RTA Anneal at 875C, 30 sec. 415 F

1/16/99 NXN Check I-V for 2um S/D spacing on curve tracer. 415 F

2/6/99 BH Ohmic metal evap ≈ 3.7 × 10-7 process #5 — Q.T 990409 A1, GaN 419, GaN 420

Parameter Film #	2	5	3	6
layer #	①	②	③	④
thickness	300 Å	2,000	400	500
metal	Ti	Al	Ni	Au

Rate incorrect so Dep stopped, once Ti thickness 317 Å

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1/26/99 Lift off Acetone 15 + 5, ~~PRS1000 100°C~~ PRS 1000 100°C, U/S 2'
JaS ✓
WT = clean
419 = numerous specks on ohmic metal. Also fine scratches.
420 = less " " " " less " "

1/27/99 BH Anneal
3 wafers WT, 419, 420

LOT #: 3 Wafer ID: NRL 319 NMD 448, 449 GaN Process OS

	Step #	Process	OSQR	DATE	SIG	Instructions
		OHMIC				
	1	Blanket Expose Al Foil Pattern	3	1/27/99	ph	Trace wafer outline with dots on Al foil using exacto knife, then retrace outline ~2mm undersize all around. Cut and trim undersized outline with scissors. If needed, flatten trimmed Al foil pattern between two glass plates. Try pattern on wafer for exposed edge fit, trim if needed. Put Al foil on round wafer carrier so that it sticks to the underside of the carrier cap for use. Put Sapphire with epi side face down on carrier. Measure Sapphire thickness on dial gauge _____ um
	2	Solvent Clean	3	1/27/99	ph	ACE 30 sec., IPA 30 sec., DI rinse 60 sec. N_2 blow dry.
	3	P/R Coat	3	1/27/99	ph	Pre-bake on vacuum hot plate, 100C, 1 min. Spin AZ 5214EIR @ 3500RPM, 30 sec. (~1.4um) Soft bake on vacuum hot plate, 100C, 1 min.
	4	Edge Bead Removal	3	1/27/99	ph	Put trimmed Al foil over wafer with edge exposed. Flood expose edges for 20 sec @ 20mW/sq.cm. on KSA aligner using soft contact. Develop for 30 sec. In 1:5=AZ351:DI DI rinse 1 min., N_2 blow dry.
	5	Ohmic Mask Align & Expose (Contact) original setting = 6.4 44	3	1/28/99	ph	Power 1 Ohmic Mask Use Soft Contact mode on KSA Aligner #1 Put dark electrical tape on wafer chuck, put Sapphire sample on top of tape. Orient it so that S-D channel will be parallel to straight edge of sample. Adjust separation dial for proper contact rainbow fringes on sample. Adjust sample so that e-beam gate markers are near sample corners with 2-3 pattern reticles included. Expose 2.9 sec. typ.for clear sample 2.7 sec typ. For dull sample (20mW/sq.cm.) Sample # Exposure time ------- --------- ------- ---------
	6	Image Reversal	3	1/28/99	ph	Post Expose Bake (PEB): On vac hot plate, 100C, 1 min. Flood Expose: On KSA aligner. 1 min. @ 20mW/sq.cm.
	7	Develop	3	1/28/99	ph	AZ351 : H_2O = 1:5 for 15 sec. 1 min. DI rinse, N_2 blow dry.

PAGE 6

	Step #	Process	OSQR	DATE	SIG	Instructions
		OHMIC continue				
	8	Inspect 448 = OK 449 = OK 319 = Dirty resist - poor contact 449 = poor contact Reworked 319 2nd litho = track resist resist stick to mask CD = 1 - 1.2 um	3	1/28	M	Optical microscope: Inspect for proper pattern expose & develop. Rough measure of 2um S-D CD using measure reticle. Take photos. SEM: Take photos of patterns and P/R sidewall profiles. Accurate measure 2um S-D CD.
	9	O_2 Plasma Clean				LF5 100W, 200mT, 2 min. Run #_____
	10	Ohmic Recess Etch				At UCSB using Cl_2 RIE Target ~ 200A based on test samples Record: recess etch _____A CL_2 RIE conditions:
	11	Pre-Metal Clean				Just prior to loading $NH_4OH : H_2O$ = 1:15, 30 sec. 1 min. DI rinse, N_2 blow dry.
	12	Ohmic Metallization				Use Bay 1 evaporator Ti – Al – Ni – Au 200 – 2000 – 400 – 500A
	13 449 & 448 mixed up bath = bad ?	Lift-Off All = very difficult lift off up 2 to 2 < 2 min. 319 = metal ribbon fall onto all devices * all devices ovetch at S-D	3	2/28		ACE soak 15 min. Ultrasonic ACE 1 min. ACE spray 15 sec., clean in ACE 30 sec., IPA 30 sec., DI 60 sec., N2 bow dry. Examine for P/R residues. If needed, use Automated lift off bath with PRS-1000 @ 100C, 60 min. 120 min. max. w/ 10 min. additional increments Record time _____ DI water spray 15 sec. DI rinse 2 min., N_2 blow dry.
	14	Inspect				Optical microscope to inspect for P/R residues Take photos. Comment:
	15	Anneal				RTA anneal @ 875C, 30 sec.
	16	I-V Check				On curve tracer, check I-V for 2um spacing. Take photos.

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LOT #: 3 Wafer ID: HRL 319 NMO 448, 449 GaN Process OS

	Step #	Process	OSQR	DATE	SIG	Instructions
		OHMIC				
	1	Blanket Expose Al Foil Pattern	3	1/27/99	ph	Trace wafer outline with dots on Al foil using exacto knife, then retrace outline ~2mm undersize all around. Cut and trim undersized outline with scissors. If needed, flatten trimmed Al foil pattern between two glass plates. Try pattern on wafer for exposed edge fit, trim if needed. Put Al foil on round wafer carrier so that it sticks to the underside of the carrier cap for use. Put Sapphire with epi side face down on carrier. Measure Sapphire thickness on dial gauge _____ um
	2	Solvent Clean	3	1/27/99	ph	ACE 30 sec., IPA 30 sec., DI rinse 60 sec. N_2 blow dry.
	3	P/R Coat	3	1/27/99	ph	Pre-bake on vacuum hot plate, 100C, 1 min. Spin AZ 5214EIR @ 3500RPM, 30 sec. (~1.4um) Soft bake on vacuum hot plate, 100C, 1 min.
	4	Edge Bead Removal	3	1/27/99	ph	Put trimmed Al foil over wafer with edge exposed. Flood expose edges for 20 sec @ 20mW/sq.cm. on KSA aligner using soft contact. Develop for 30 sec. In 1:5=AZ351:DI DI rinse 1 min., N_2 blow dry.
	5	Ohmic Mask Align & Expose (Contact) Original Setting = 6.4 44	3	1/28/99	ph	Power 1 Ohmic Mask Use Soft Contact mode on KSA Aligner #1 Put dark electrical tape on wafer chuck, put Sapphire sample on top of tape. Orient it so that S-D channel will be parallel to straight edge of sample. Adjust separation dial for proper contact rainbow fringes on sample. Adjust sample so that e-beam gate markers are near sample corners with 2-3 pattern reticles included. Expose 2.9 sec. typ.for clear sample 2.7 sec typ. For dull sample (20mW/sq.cm.) Sample # Exposure time -------- ---------- -------- ----------
	6	Image Reversal	3	1/28/99	ph	Post Expose Bake (PEB): On vac hot plate, 100C, 1 min. Flood Expose: On KSA aligner, 1 min. @ 20mW/sq.cm.
	7	Develop	3	1/28/99	ph	AZ351 : H_2O = 1:5 for 15 sec. 1 min. DI rinse, N_2 blow dry.

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RCE: HRL)

LOT #: 3 Wafer ID: HRL # 319 NMD 448 449

	Step #	Process	OSQR	DATE	SIG	Instructions
		OHMIC continue				
	8	Inspect 448 = OK 449 = OK 319 = Dirty resist - poor contact 449 = poor contact Reworked 319 2nd litho = crack resist resist stick to mask CD = 1 - 1.2um	3	1/28	M	Optical microscope: Inspect for proper pattern expose & develop. Rough measure of 2um S-D CD using measure reticle. Take photos. SEM: Take photos of patterns and P/R sidewall profiles. Accurate measure 2um S-D CD.
	9	O_2 Pl				
	10	Ohmi				st samples __A
	11	Pre-M				c. y.
	12	Ohmic				
	13	Lift-Off All = very difficult lift off up 2+2+2 min. 319 = metal ribbon fall onto all devices all devices ended at S-D 449 & mixed up bath = bad	3	2/28	M	ACE soak 15 min. Ultrasonic ACE 1 min. ACE spray 15 sec., clean in ACE 30 sec., IPA 30 sec., DI 60 sec., N2 bow dry. Examine for P/R residues. If needed, use Automated lift off bath with PRS-1000 @ 100C, 60 min. 120 min. max. w/ 10 min. additional increments Record time _____ DI water spray 15 sec. DI rinse 2 min., N_2 blow dry.
	14	Inspect				Optical microscope to inspect for P/R residues Take photos. Comment:
	15	Anneal				RTA anneal @ 875C, 30 sec.
	16	I-V Check				On curve tracer, check I-V for 2um spacing. Take photos.

ohmic recess etch
Jan OR Feb. 1999

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LABORATORY NOTEBOOK

Notebook No.: 5007

Assigned to: Nguyen X. Nguyen

Date: 12/18/97

Etching Experiment with Cl_2 ECR System:

⇒ First trial: 200 W / 4 mT / 10 sccm → ~700 Å/min.

100 W / 4 mT / 10 sccm → 350 Å/min.
300 W / 4 mT / 10 sccm → Unstable plasma, no reliable data.
400 W " " → " " "

200 W w/ Vary Pressure.

			2 min Etching
4 mT	(Top Mag Only)	Unstable → Stable	3245 Å
6 mT	(Top Mag Only)	Stable	3095 Å
8 mT	(Both Magnet)	Unstable → Stable	No data
10 mT	(Both Magnet)	Stable	200 → 300 Å.

250 W → 4 mT No Run (Power shut off)

250 W → 8 mT

Recent etch data:

200 W w/ 4 mT. Top mag only → ~1,000 Å (twice)

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Read and Understood By

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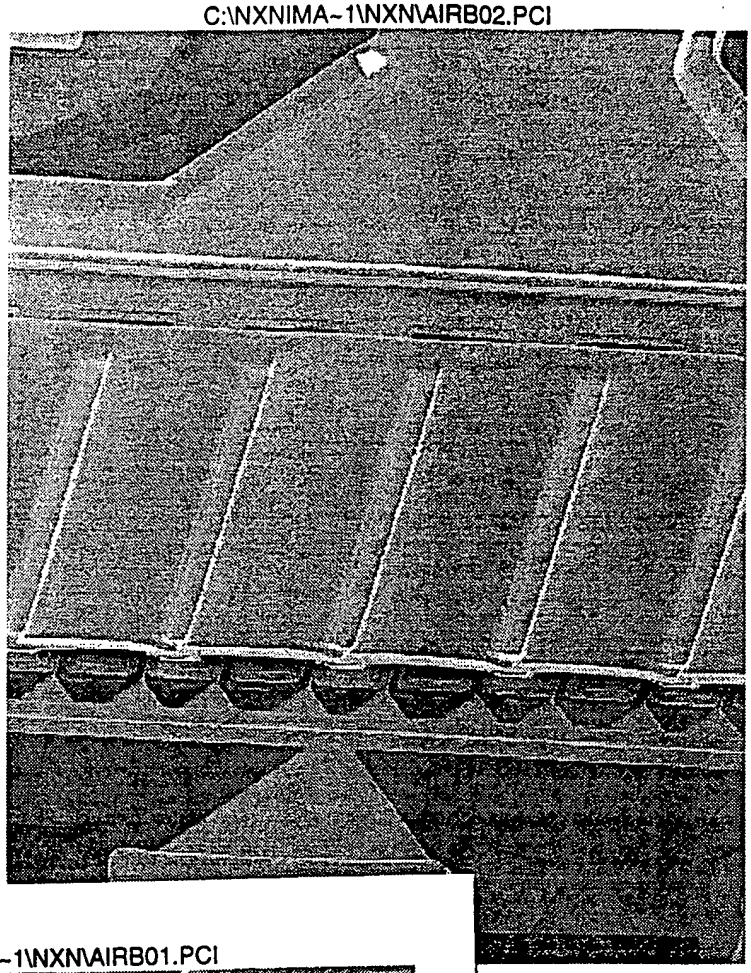

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PAGE 19

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Signed

Date

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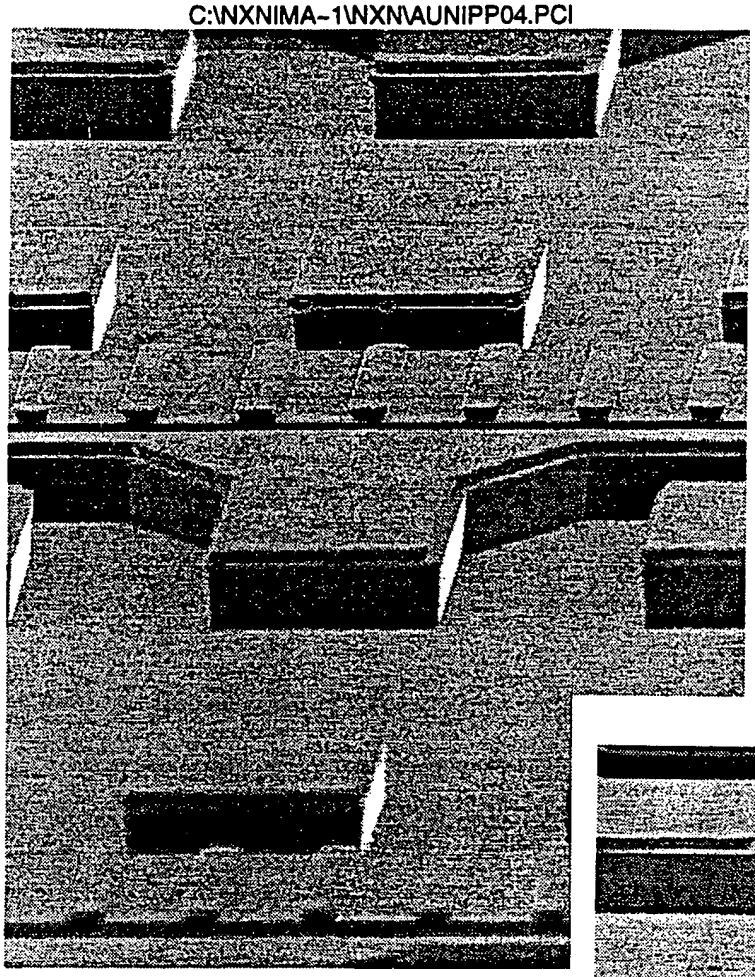

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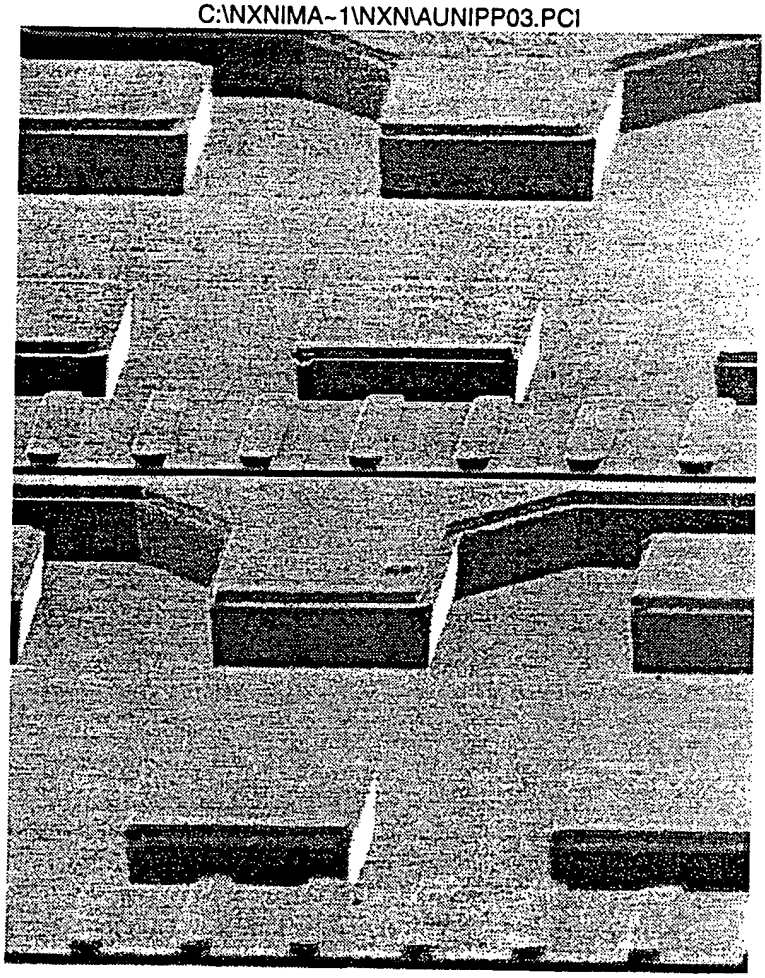

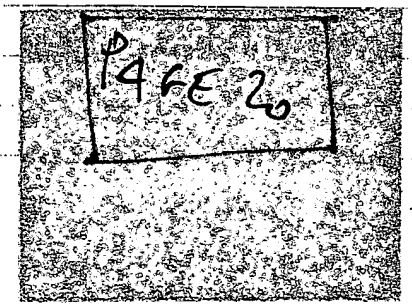

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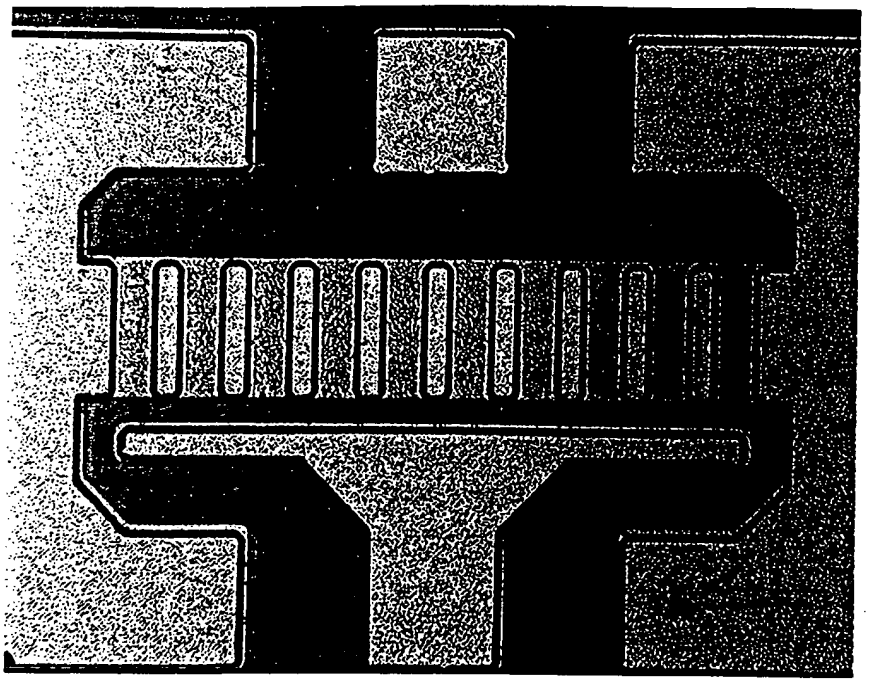

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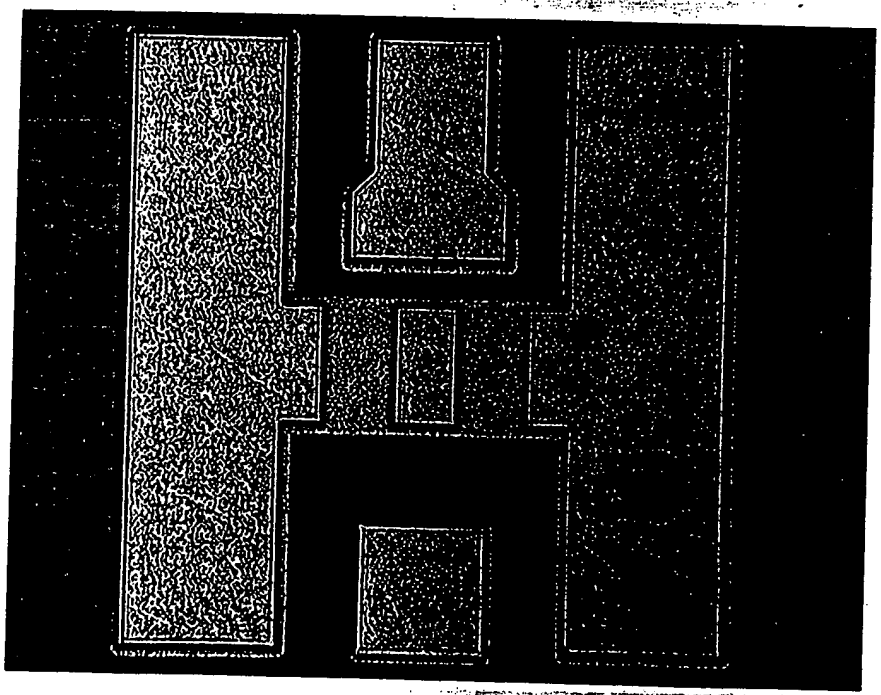

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Signed Date Signed Date

PROJECT _____

Notebook No. _____

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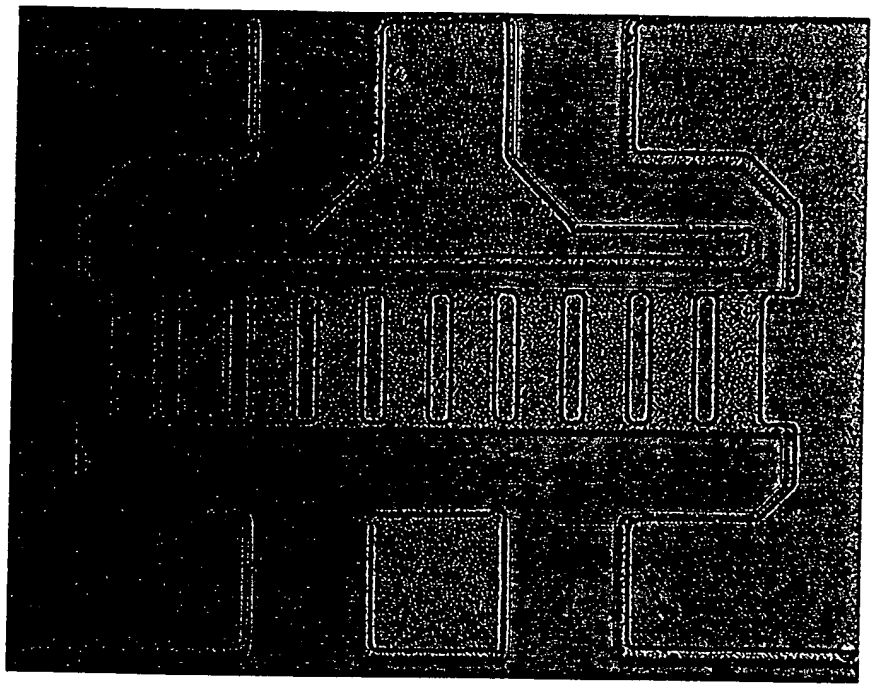

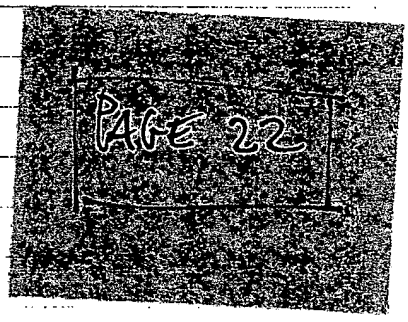

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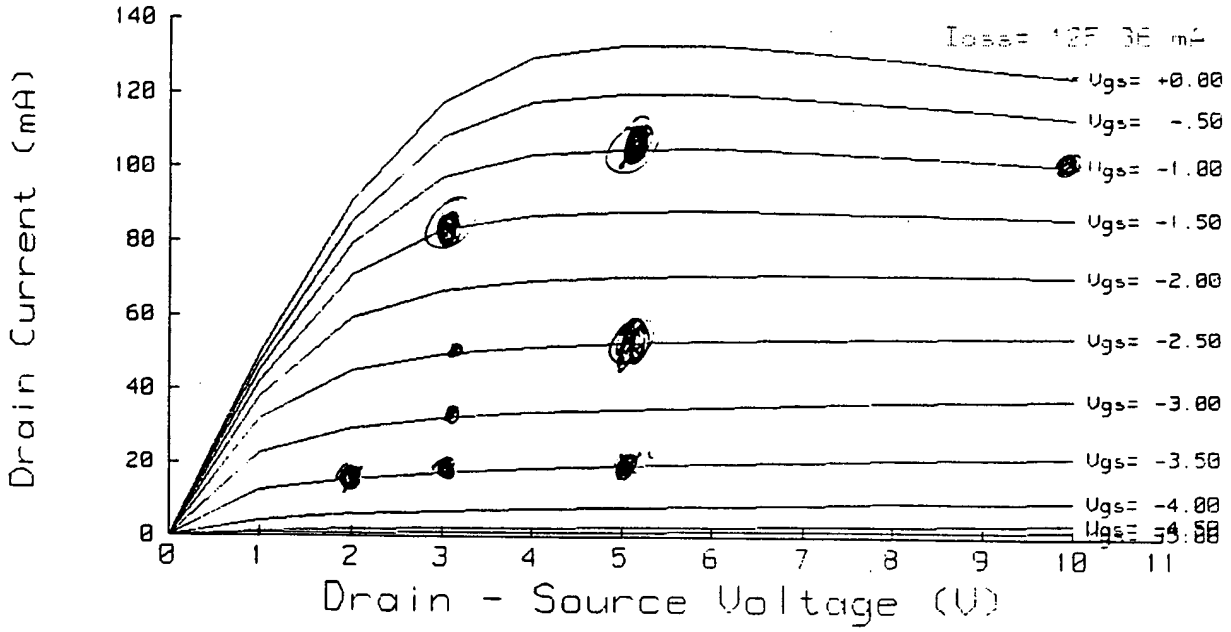
Read and Understood By

Noise measurement w/ P. Harvey.

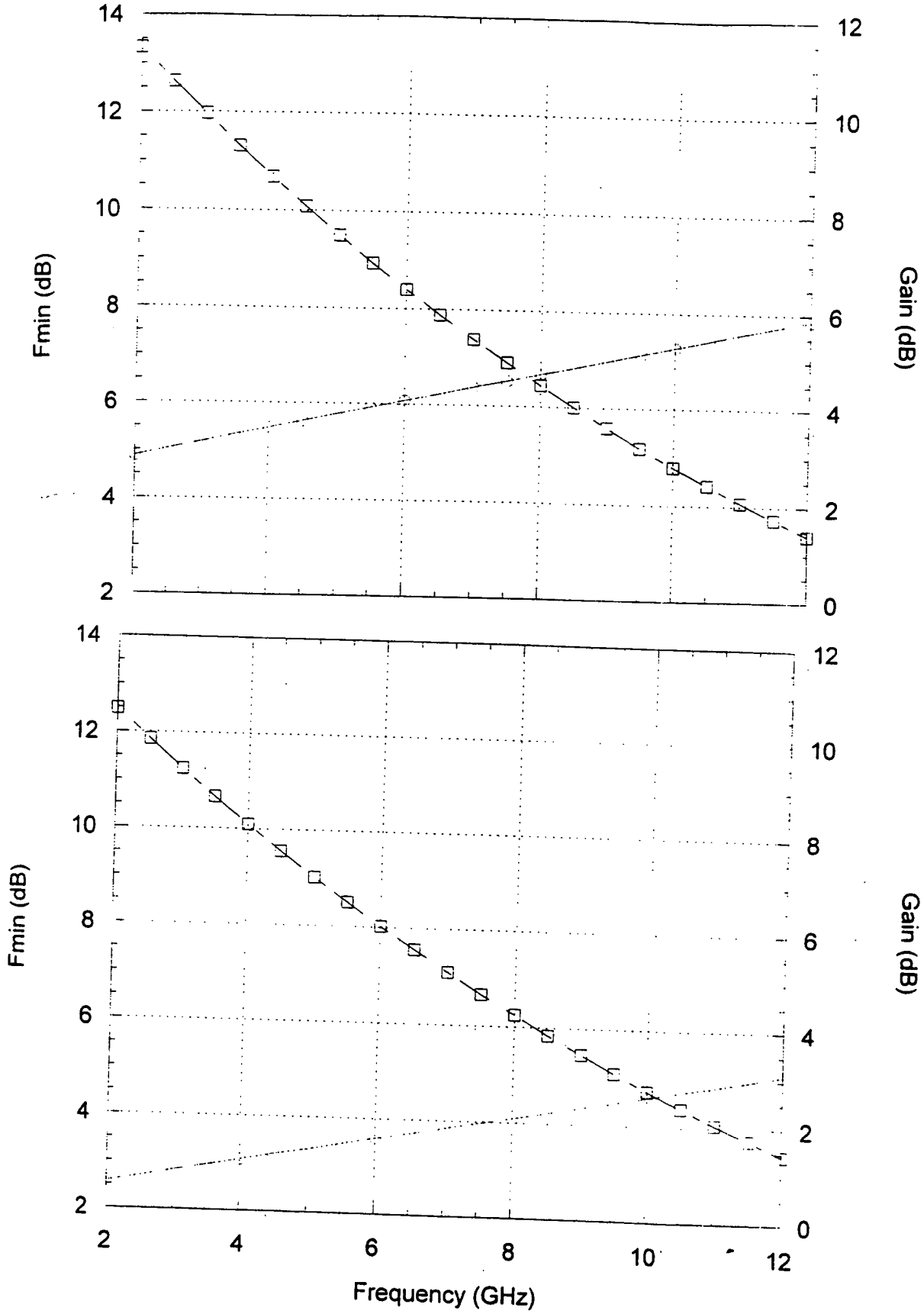
Gen 253 - gn0190501 - 505!-9C $V_{ds} = 10V$; $V_g = -1.0V$

gn0190325 - $V_{ds} = 3V$; $V_g = -2.5V$

DRAIN CURRENT vs. DRAIN-SOURCE VOLTAGE



Signed Date Date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Gain (dB)
Frequency (GHz)
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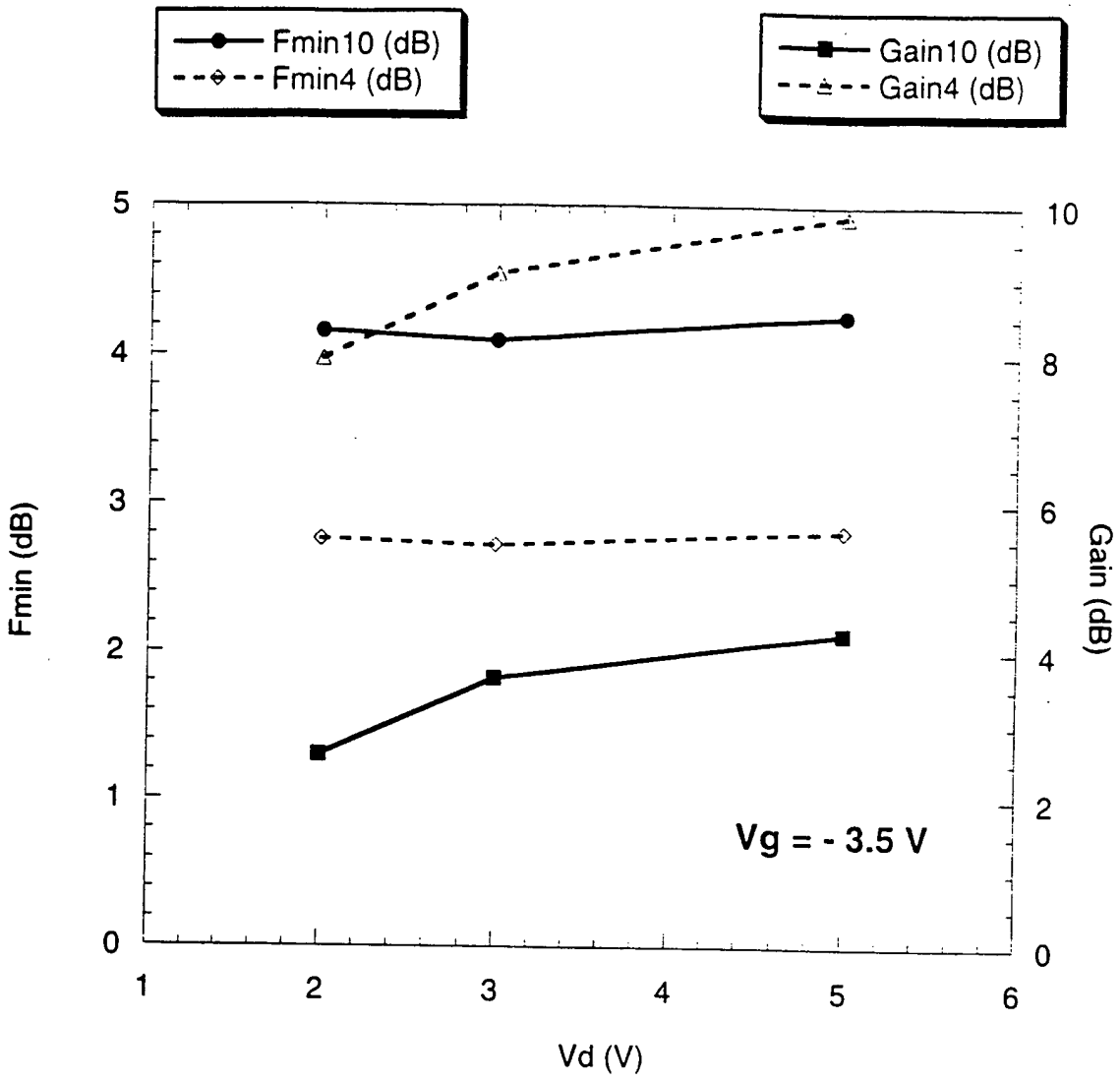
10
8
6
4
2
0
2
4
6
8
10
12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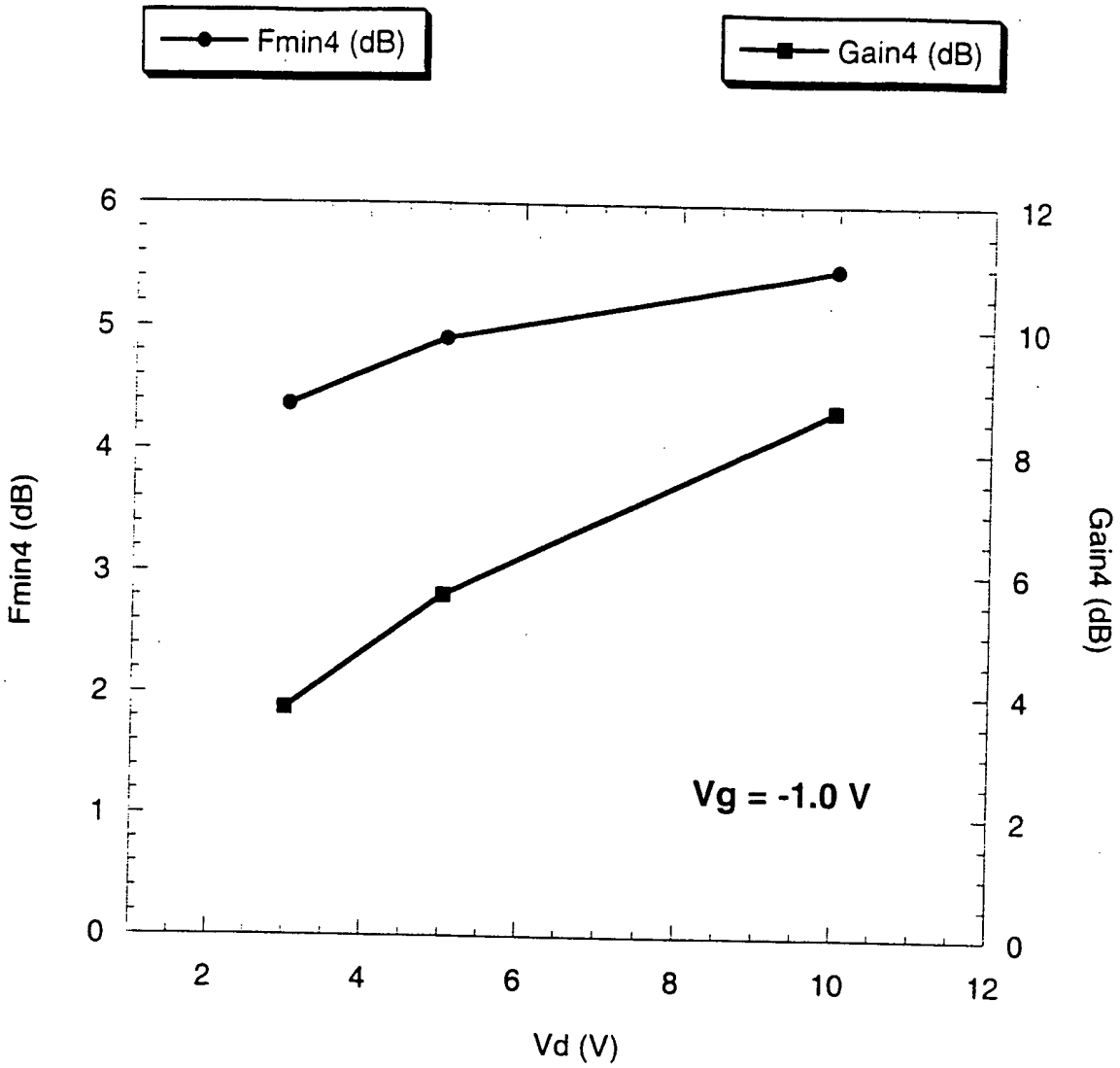
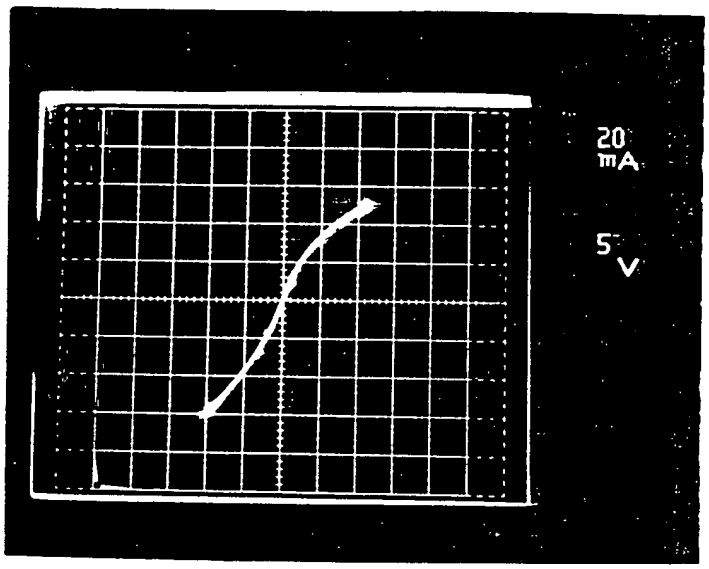
Fmin4 (dB)
Gain10 (dB)
Gain4 (dB)
Fmin (dB)
Gain (dB)
Vd (V)
Vg = - 3.5 V
0
1
2
3
4
5
6
0
2
4
6
8
10
1
2
3
4
5
6

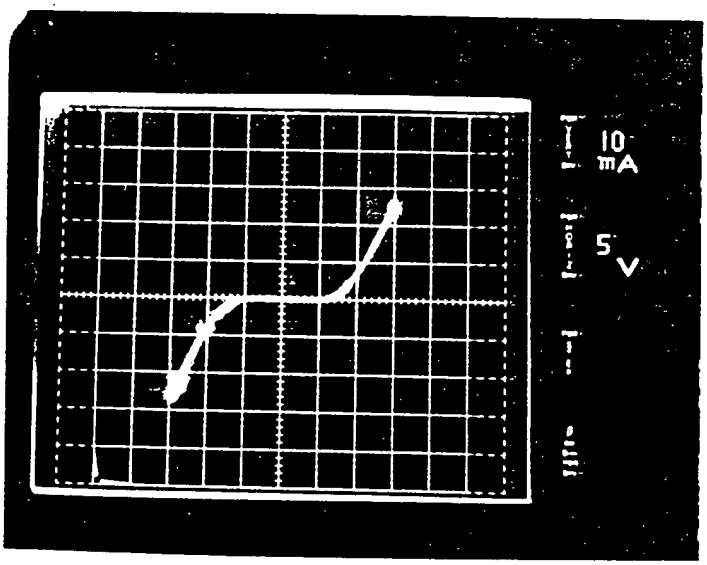

Fmin4 (dB)
Gain4 (dB)
6
5
4
3
2
1
0
12
10
8
6
4
2
0
2
4
6
8
10
12
Fmin4 (dB)
Gain4 (dB)
Vg = -1.0 V
Vd (V)

Date



Prior to annealing.
After metal deposition.

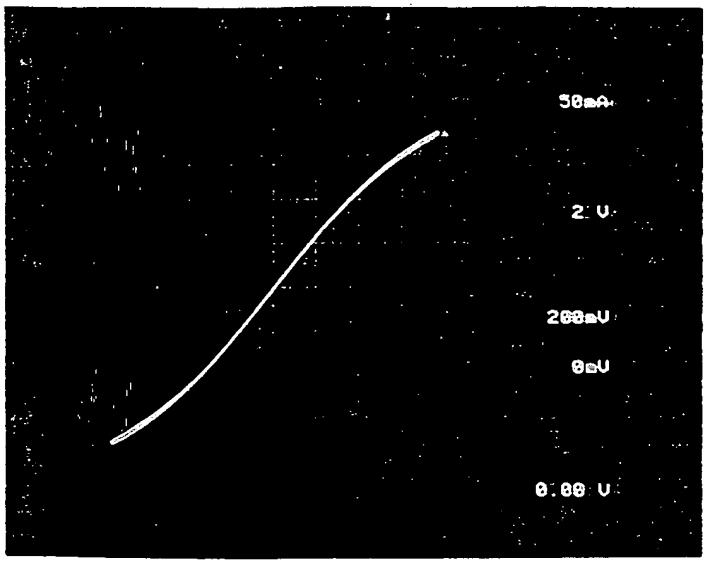
Coil 250

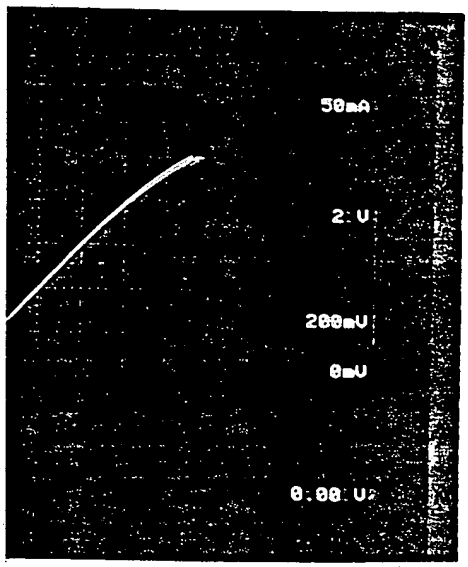


Coil 285.

Signed

Date


50mA
2:U
200mU
0mU
0:00 U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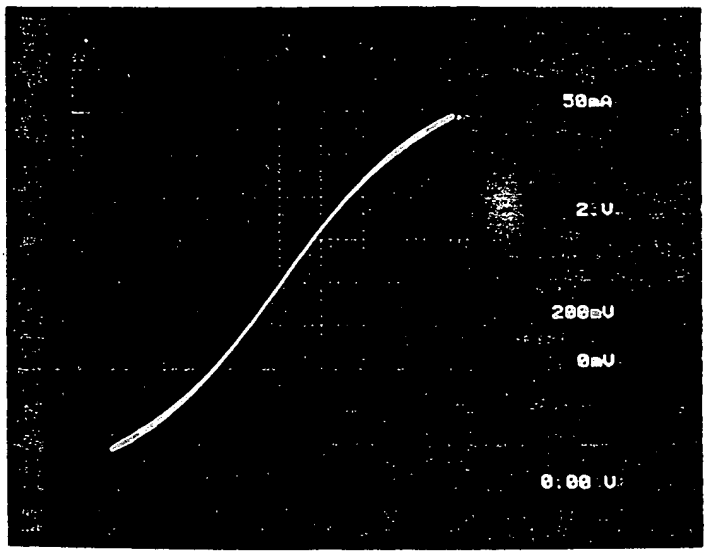
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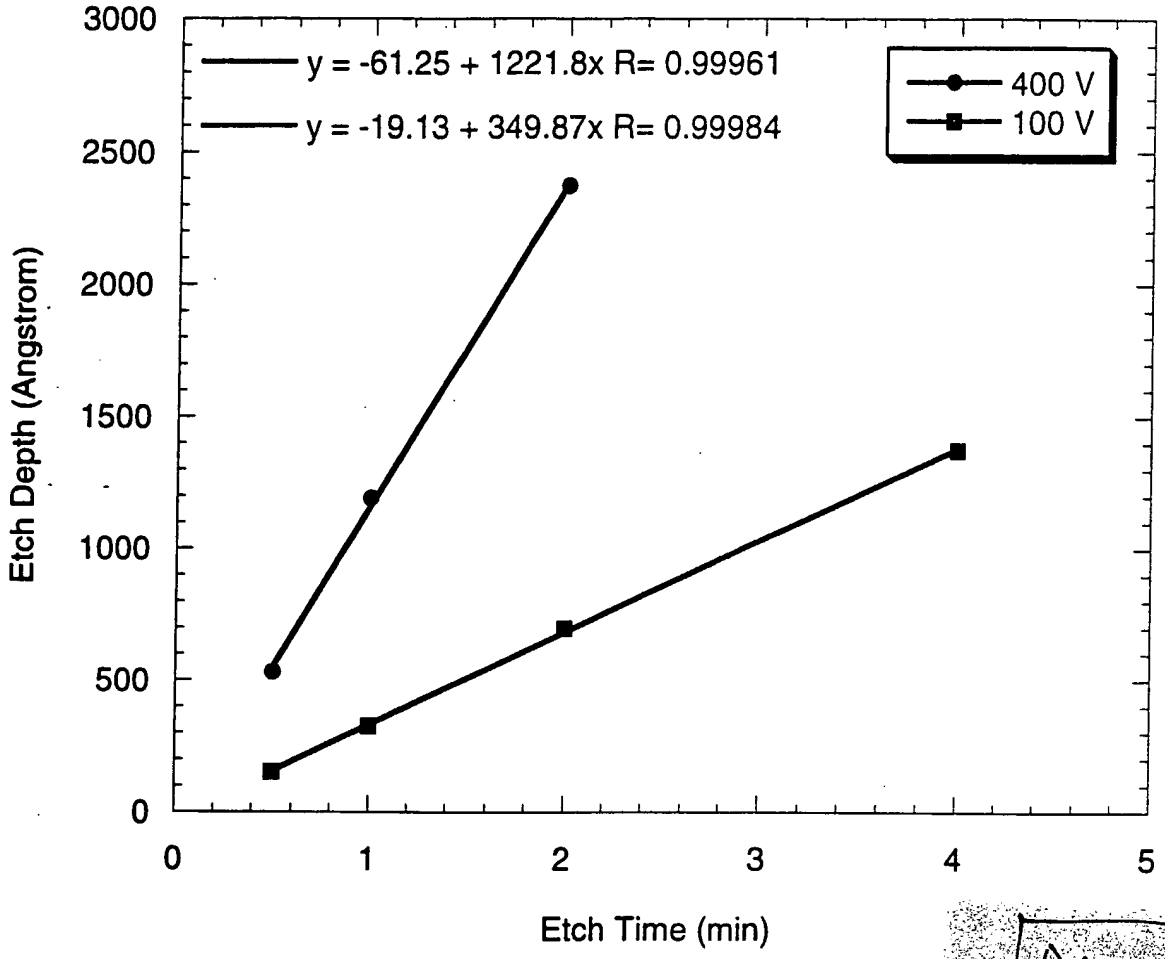

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Etching conditions:

Base Pressure: $4-5 \times 10^{-6}$ T

Cl_2 Flow: 18 sccm.

Chamber Press: 5 mT.

Power @ 400V – 185-191 W; $P_{reflected}$ – 5 W.
@ 100V – 44-47 W; P_r – 0 W.

H = 3.2" high end.

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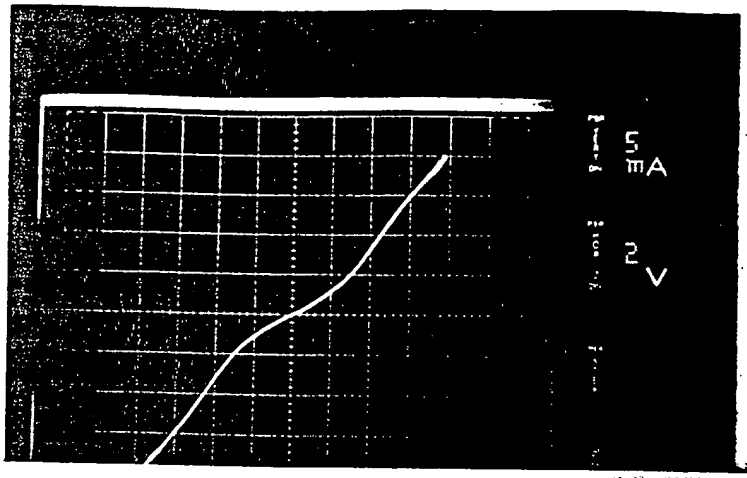

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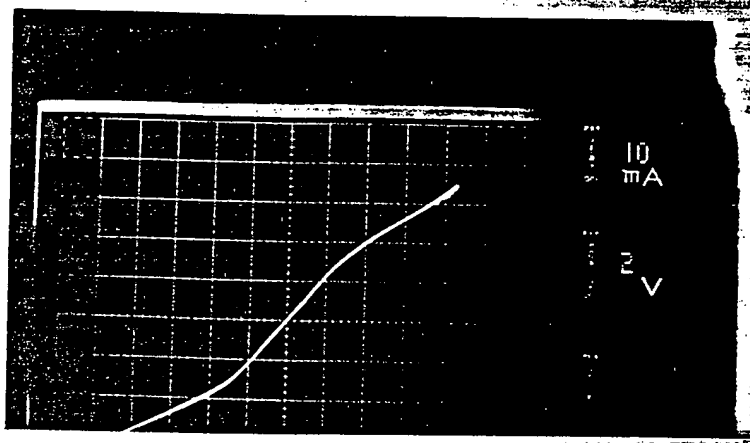
PAGE 12



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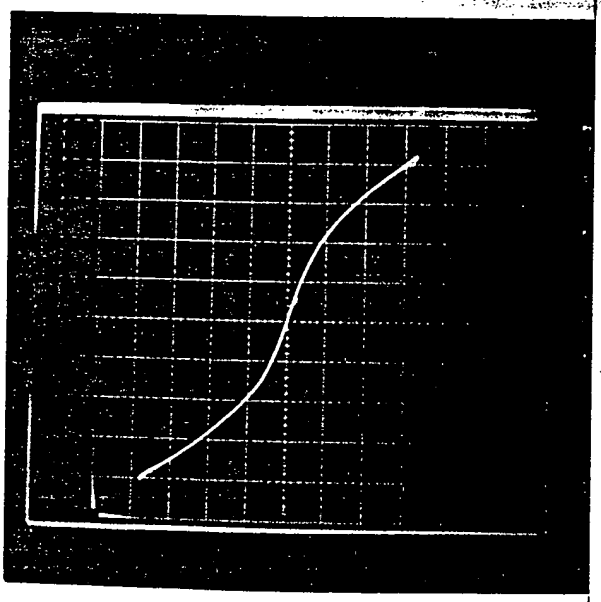

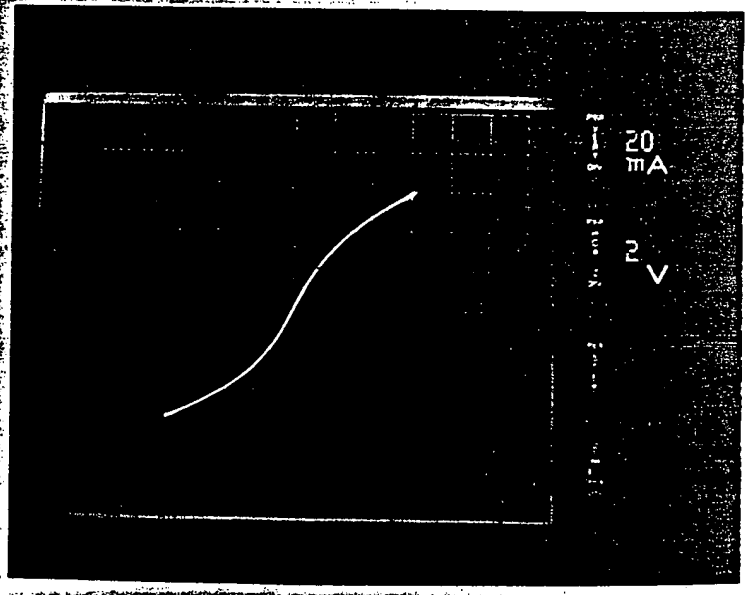

1'20" Etching

2'0" Etching

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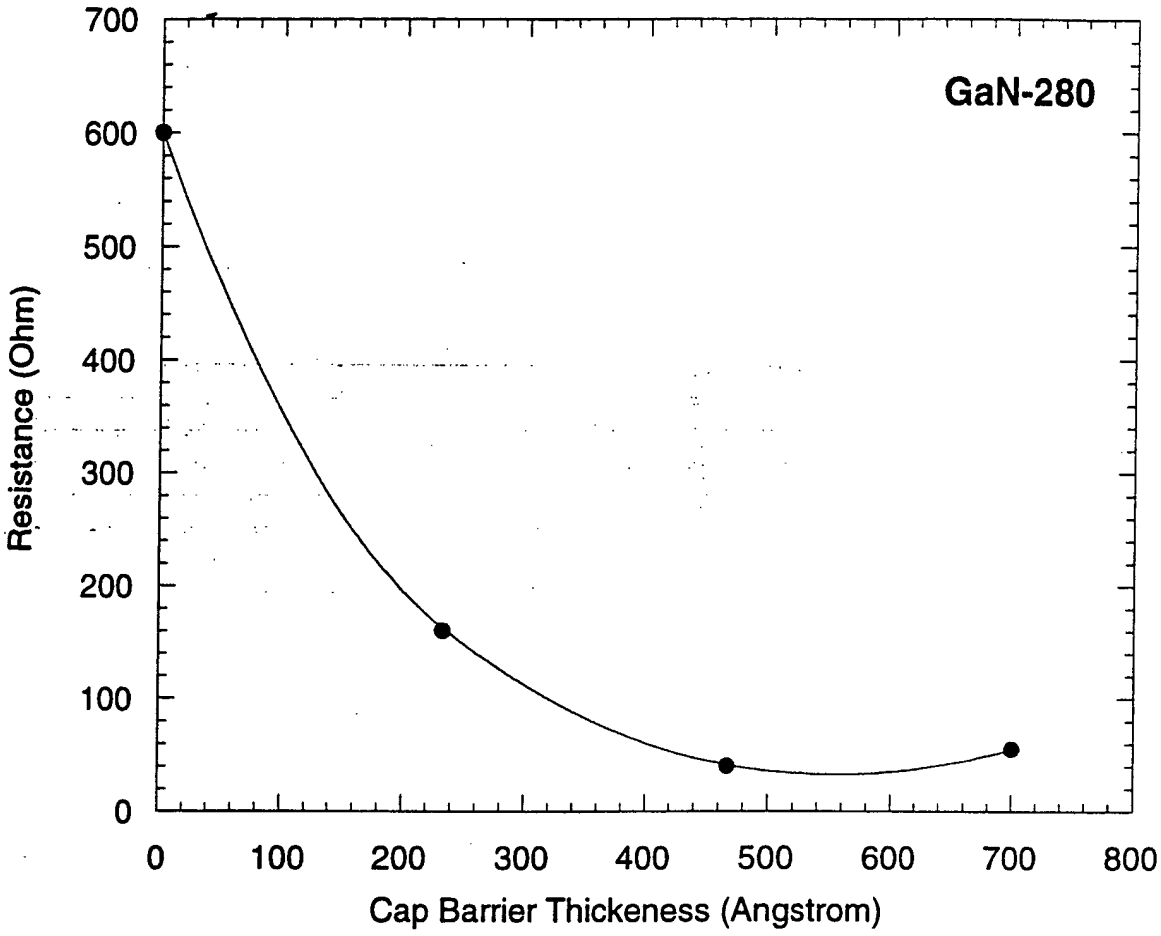
Read and Understood By

Signed Date Signed Date



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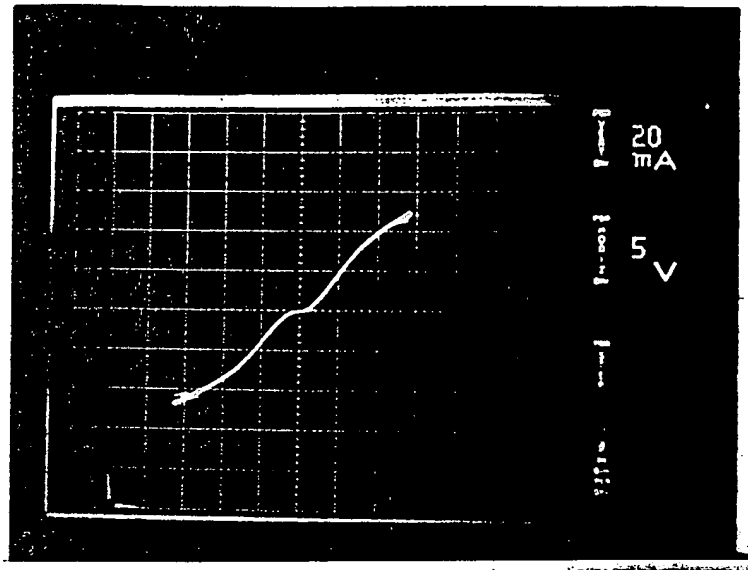

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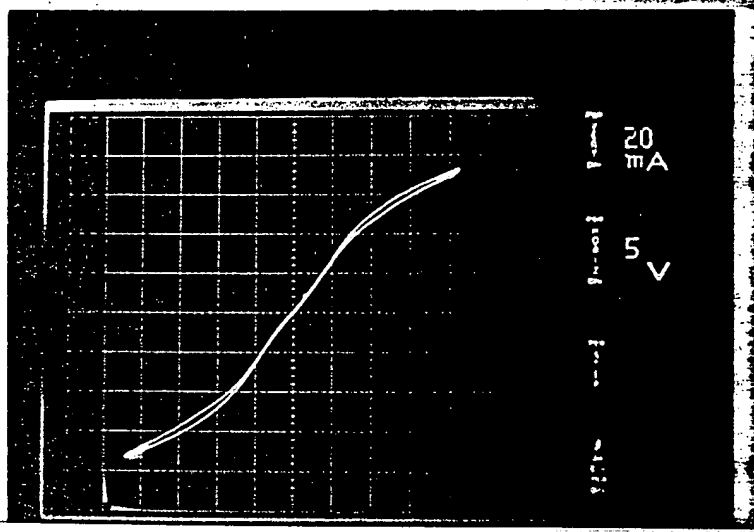

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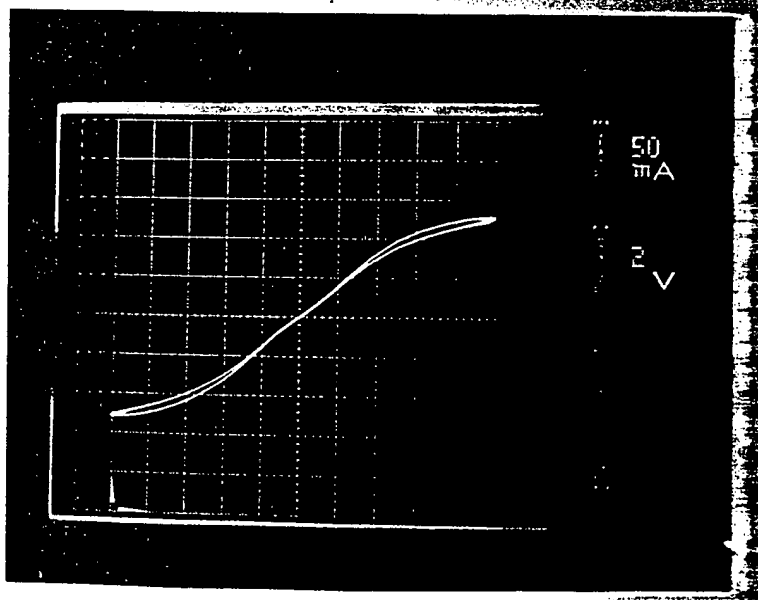

← 2'0" Etching

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Understood By

Signed Date Signed Date

Notebook No. _____

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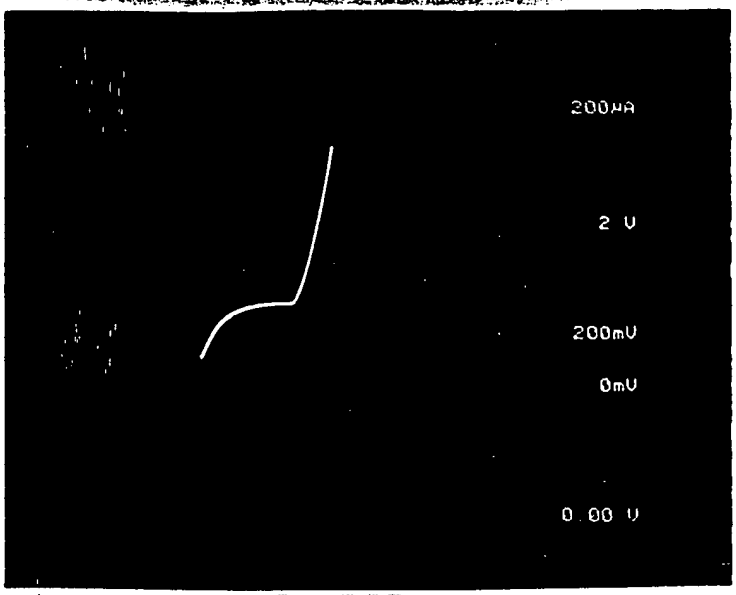

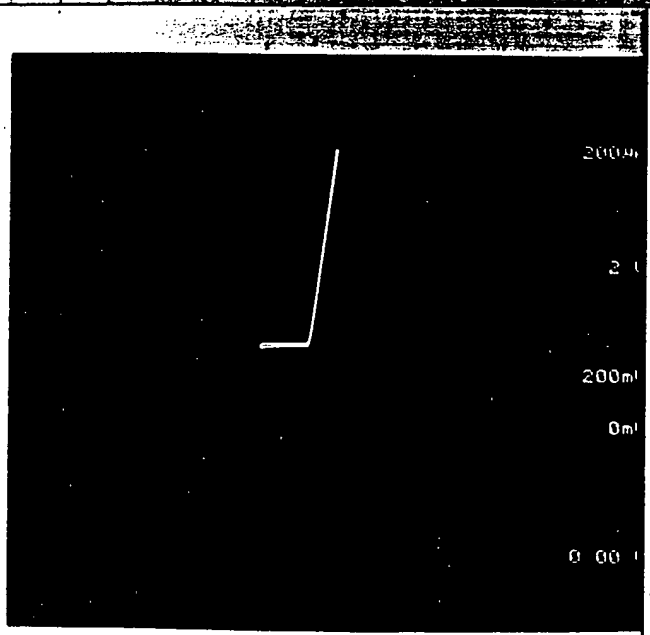

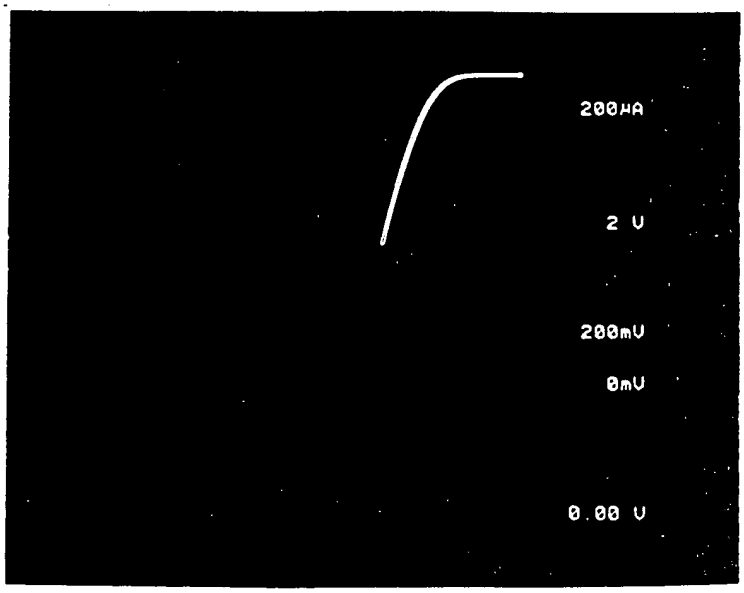

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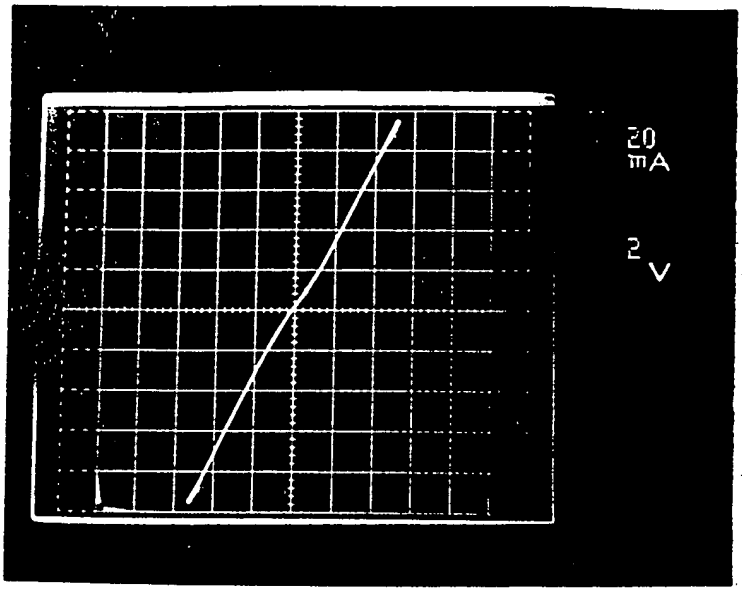

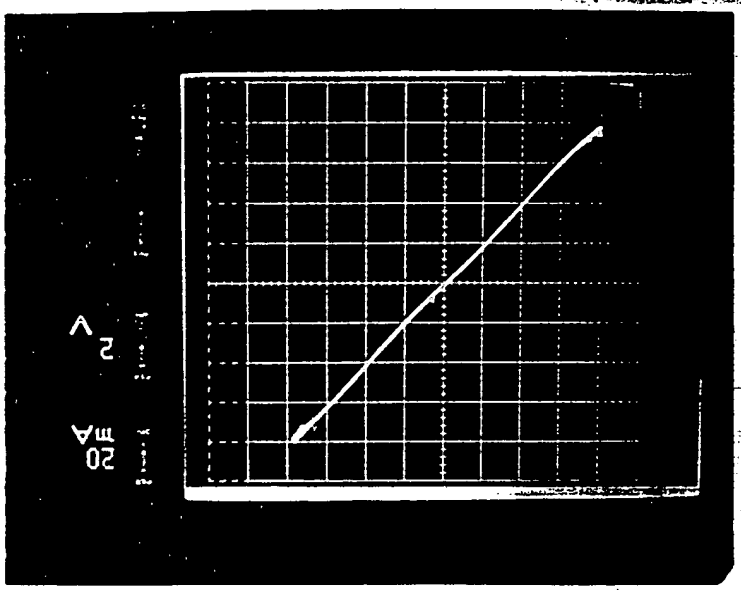

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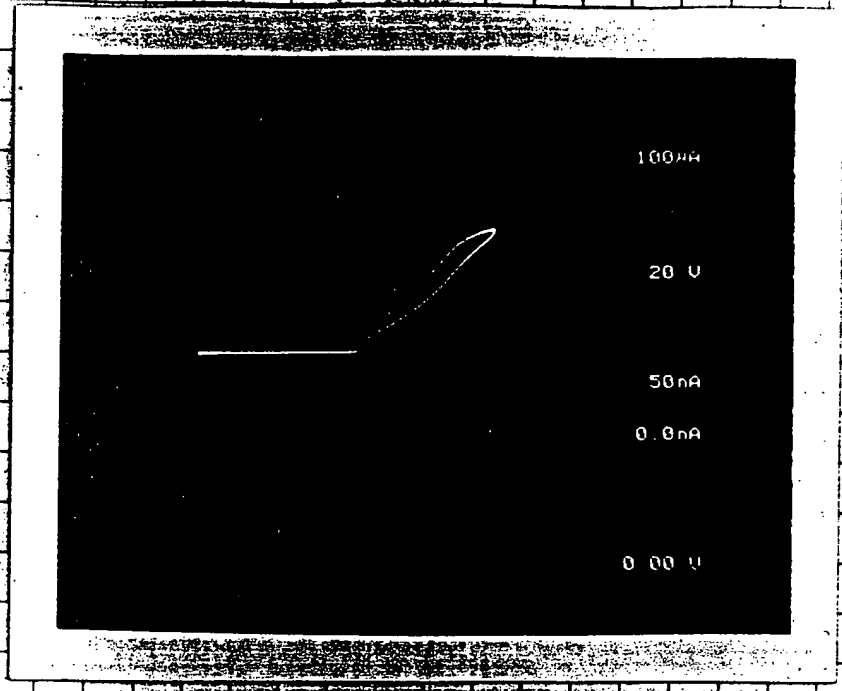
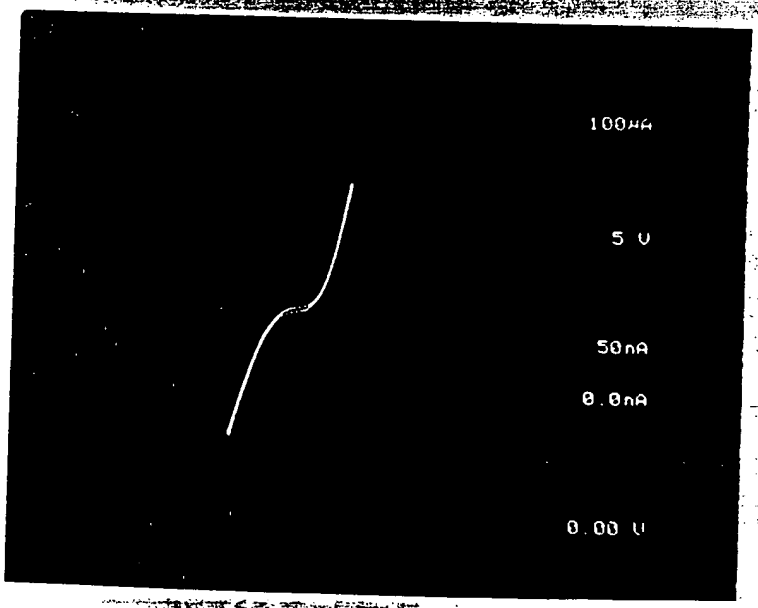
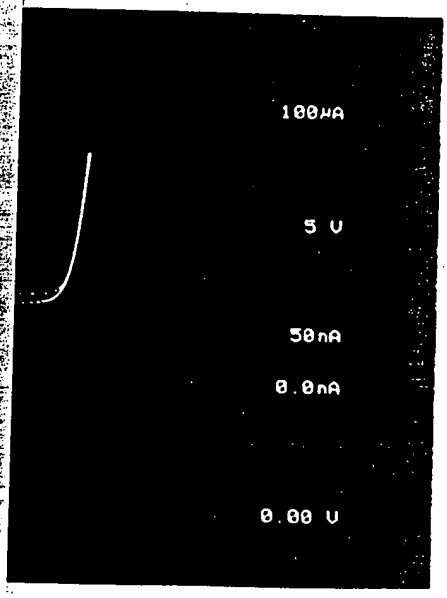
Signed	Date	Signed	Date



981021 FE





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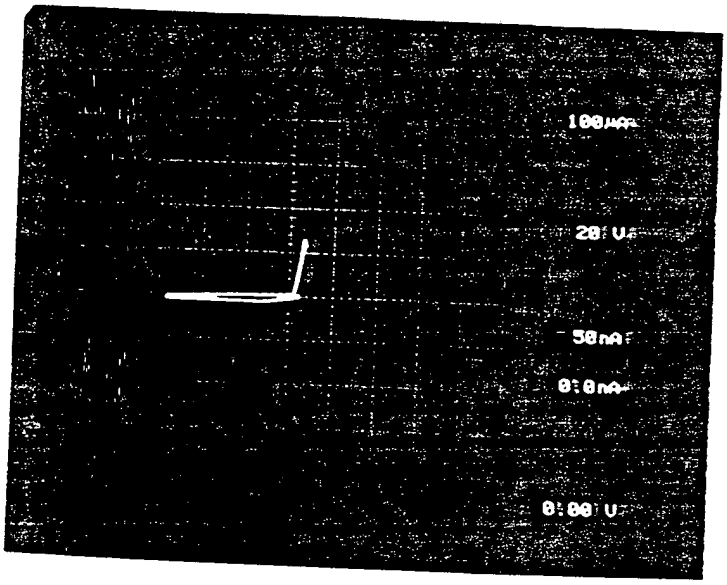
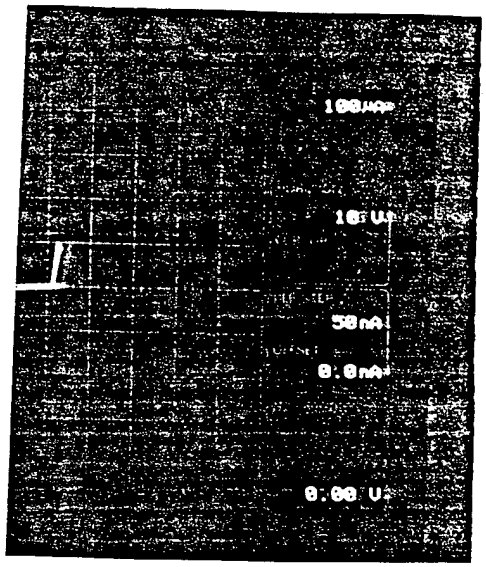
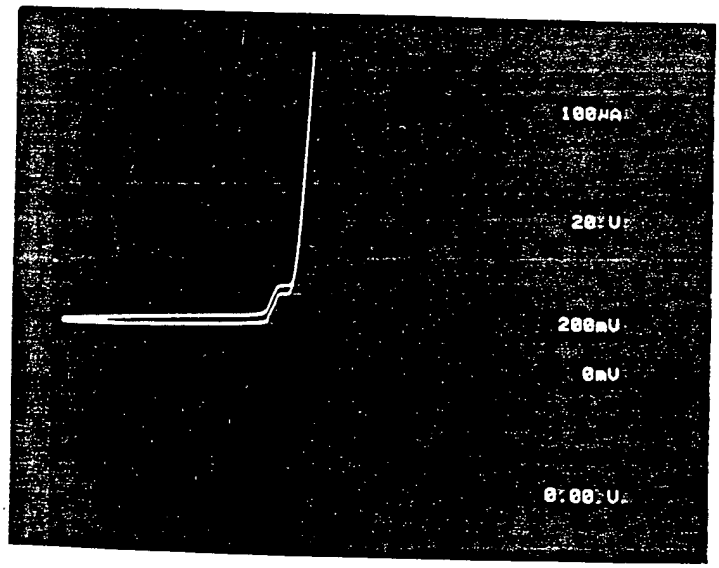
Signed _____ Date _____ Signed _____ Date _____

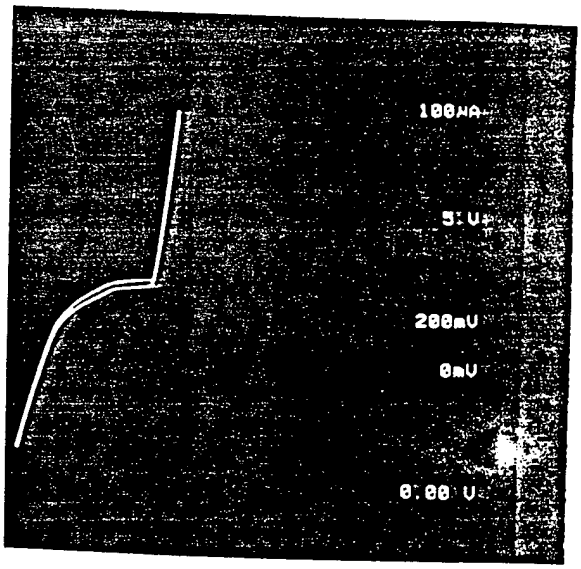
← 98(02)FD →







GN-299



GN-295

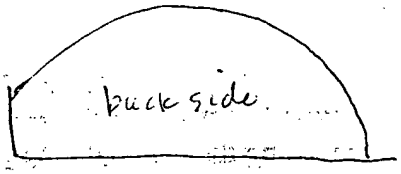
Signed

GaN 415

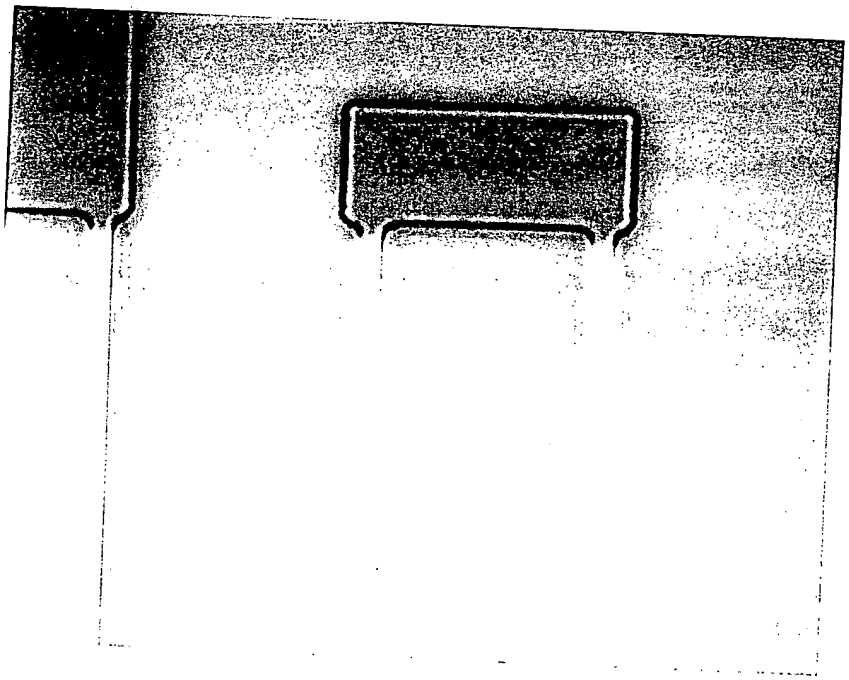
GaN 420
sapphire

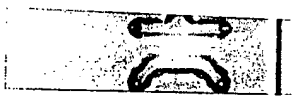
415  flat

415 No flat 

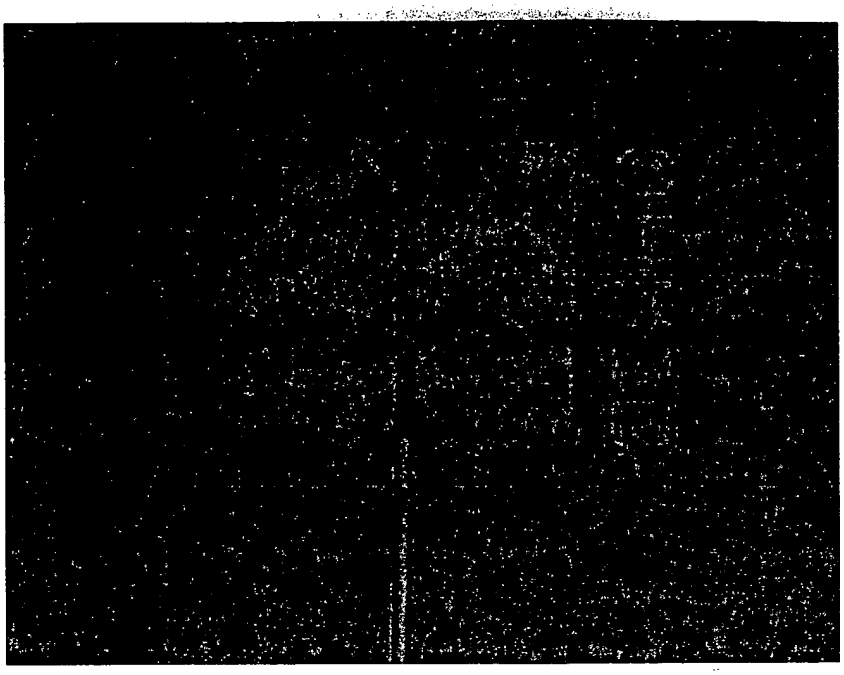
WT 990409A1 

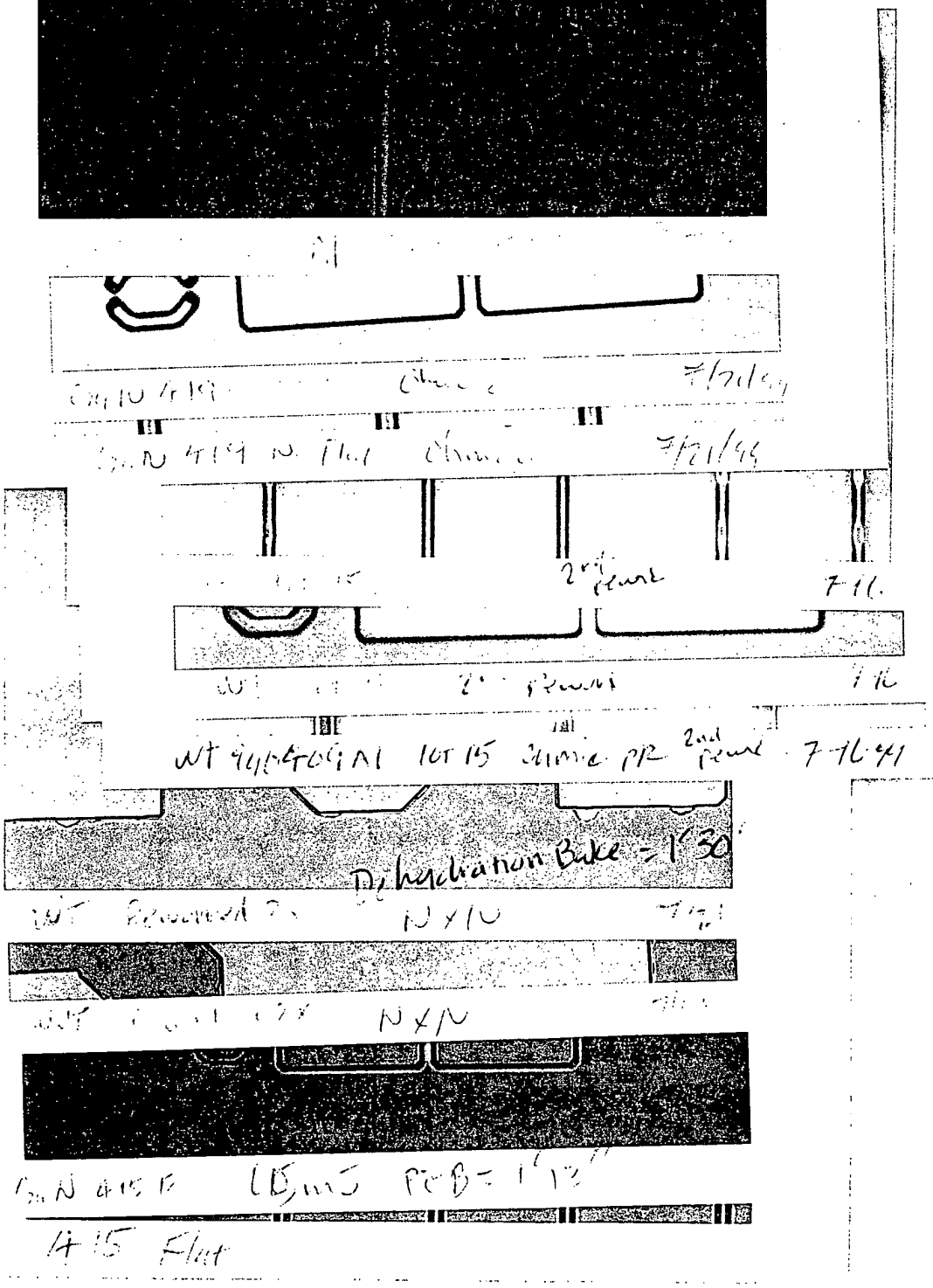
GaN 419 = No Flat 
sapphire

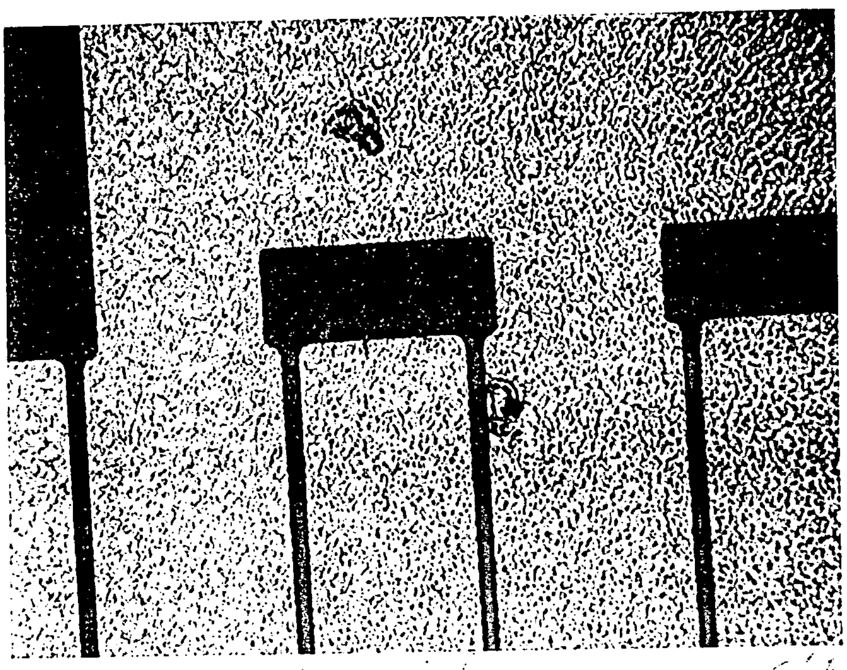




GaN 415 lot 15 chunk 7-13-99




Dehydration Bake = 1'30"
4 15 Flat



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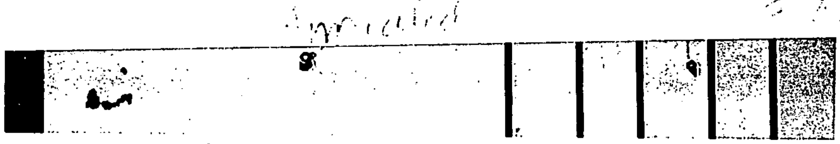
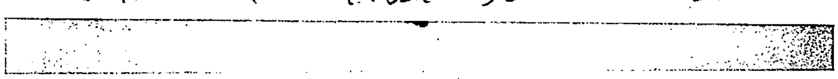
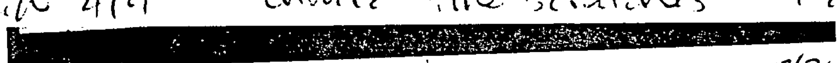


GaN 419 ohmic scratch 7-26



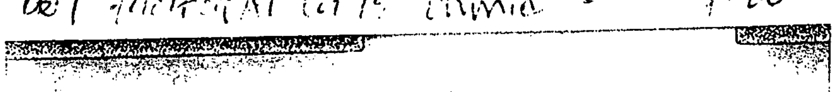
GaN 419 ohmic fine scratches 7-26



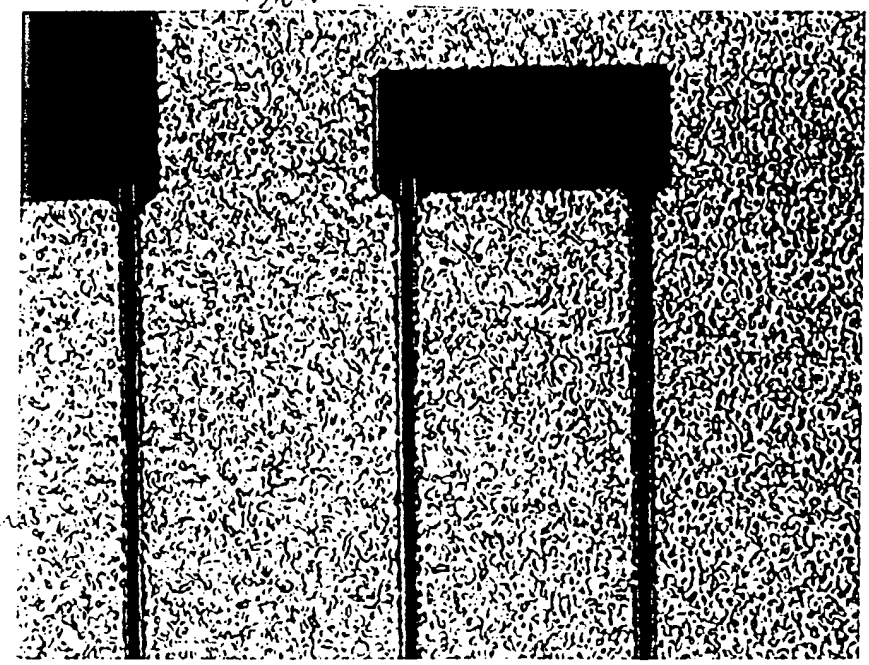
7/26
GaN 419 ohmic

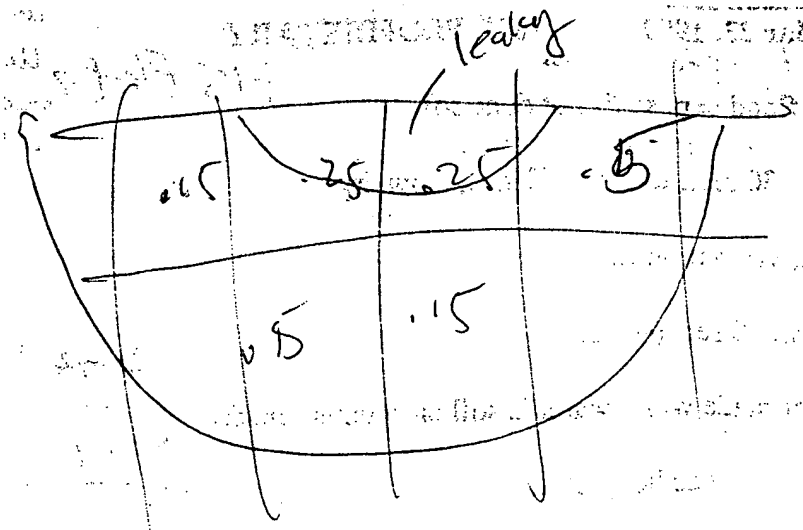
GaN 419 ohmic [illegible] 7-26-96

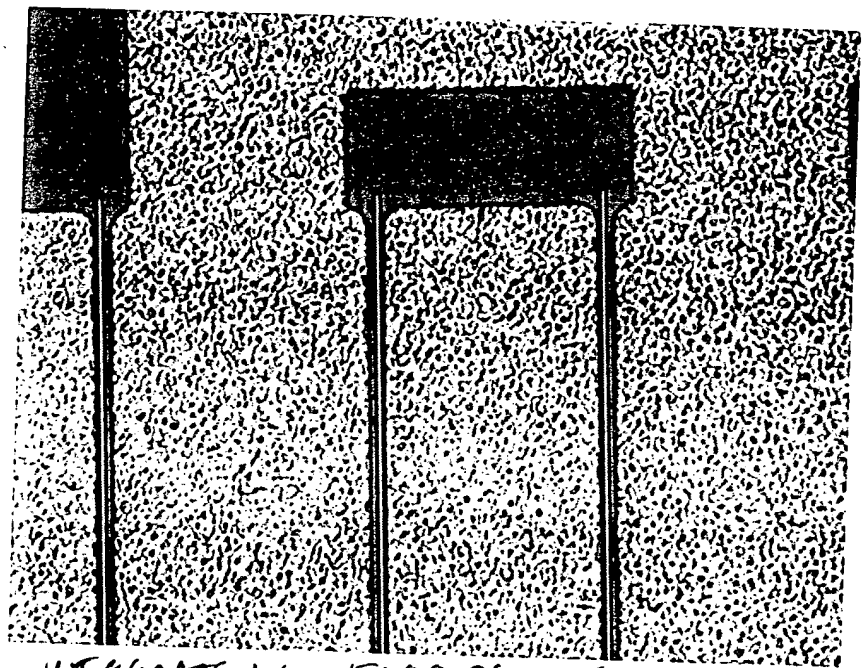
UCT [illegible] lot 15 ohmic [illegible] 7-26



B[illegible] N 415 F [illegible] 7-26-96



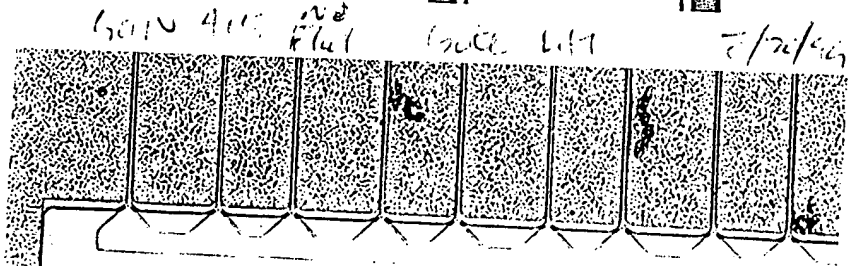




WT940409A1 15048 86 0.15mm 7-10-94

5051:86 WT940409A1 0.5mm 8-10-94

WT 940409 5040 86 0.25mm 9-10-94



5050:86

Exposure Request

Wafer Without Traveller

Date: 2-4-99 By: Paul Soo / Danny C443

This section to be completed by submitter

Wafer #	GaN 419 GaN 420
Charge #:	BDGN3AL
Mask Set	Power 1
Pattern to be Exposed (ie gate layer, ohmic, etc)	gate
Required Resist Coating:	
CD Target	0.25 μm
Tolerance	

PRIORITY # 2 à 3

This section to be completed when coated

Resist Coating Date:_____ By:_____

PMMA	Copolymer	PMMA

This section to be completed when exposed

Exposure Parameters Date:_____ By:_____

Pattern name

L

B

G

S

D

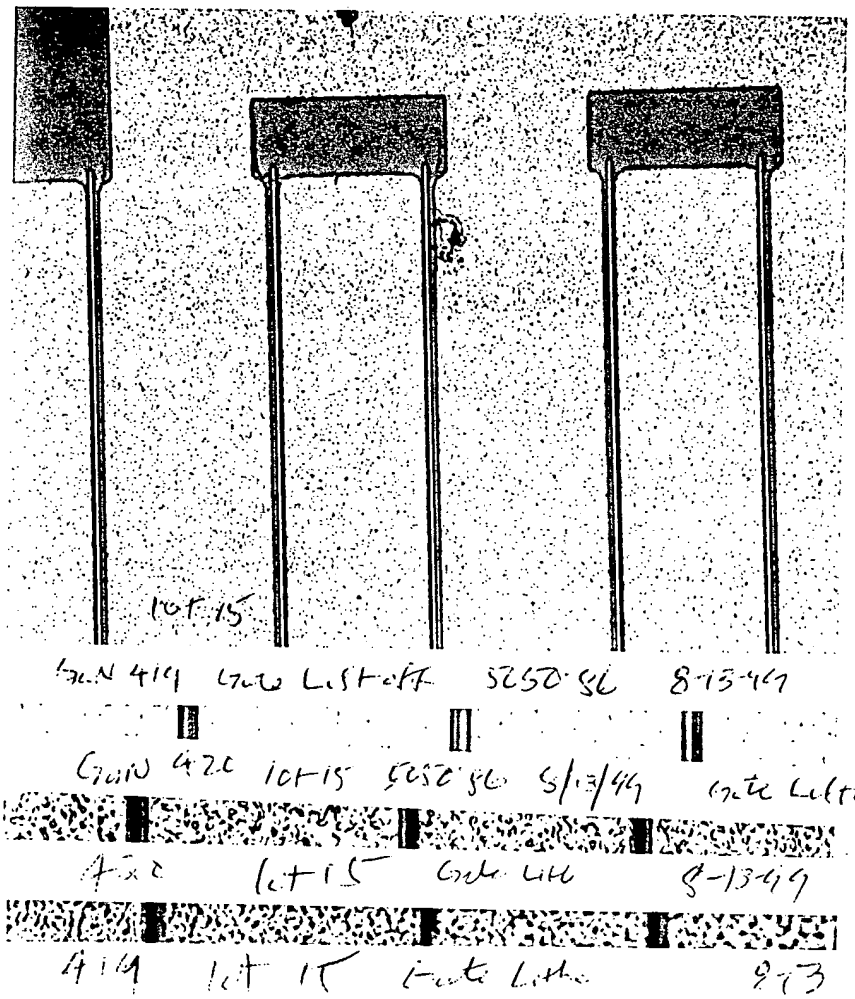
1.

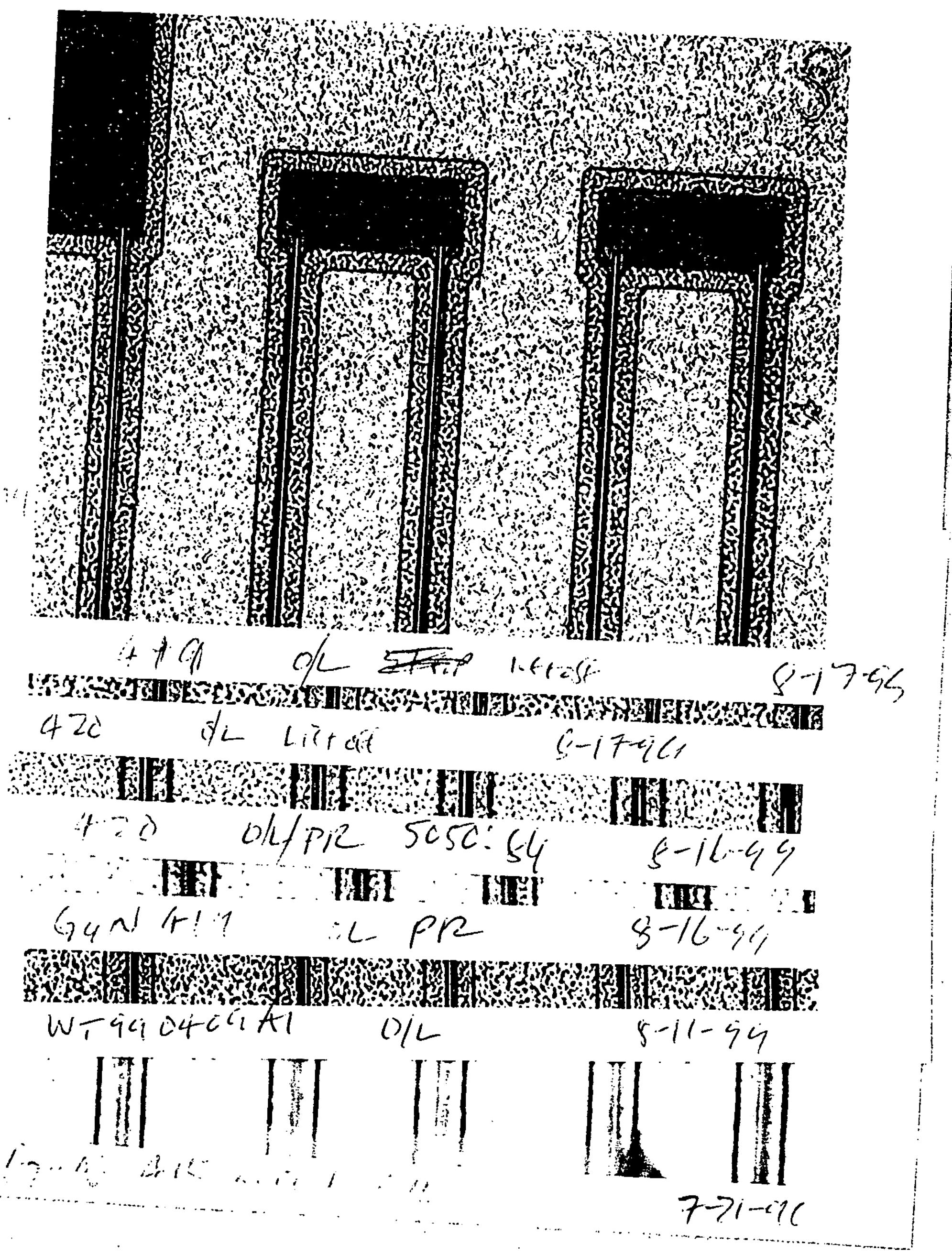
Re

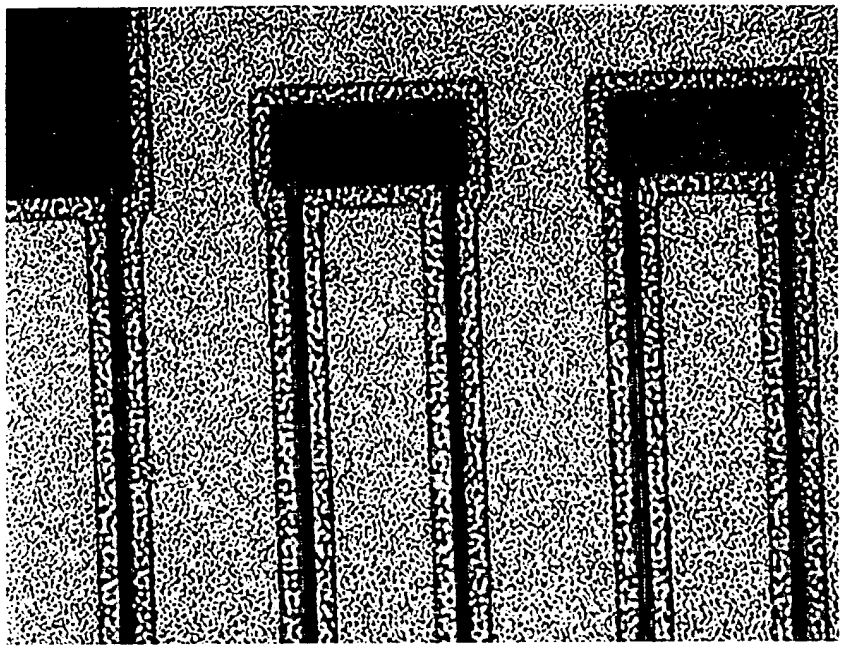
Me

IPA

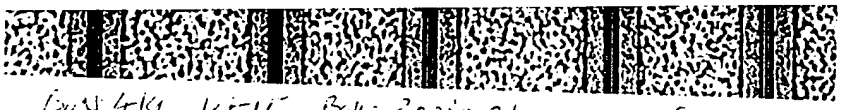
IPA



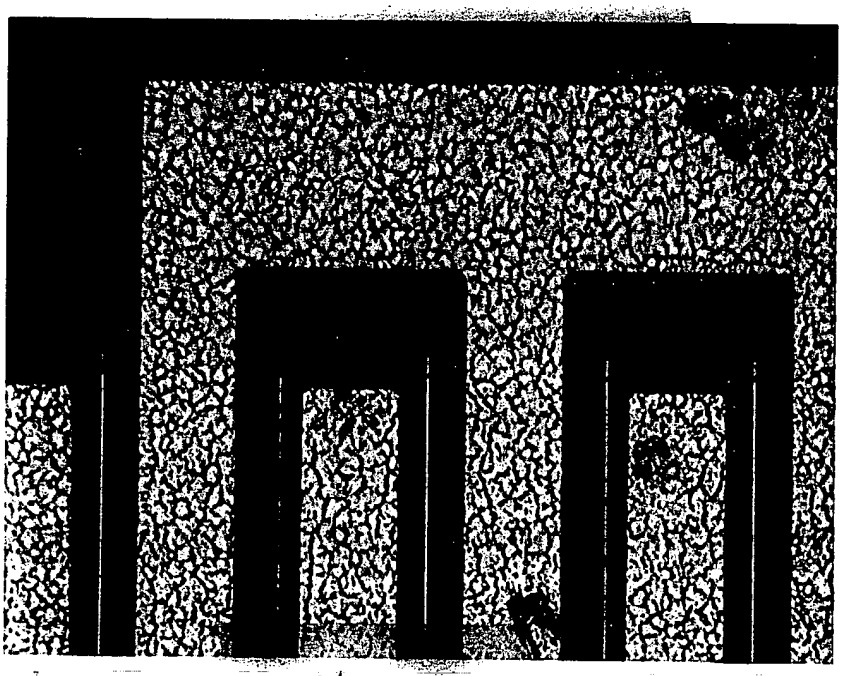

419 O/L 8-17-99
420 O/L 8-17-99
420 O/L/PR 5050:84 8-16-99
G4N 419 O/L PR 8-16-99
WT990406 A1 O/L 8-11-99
7-21-99



GaN 42C 1cf-15 Bake 300°C 2hrs 5-17-94



GaN 41C 1cf-15 Bake 300°C 2hrs 5-17-94

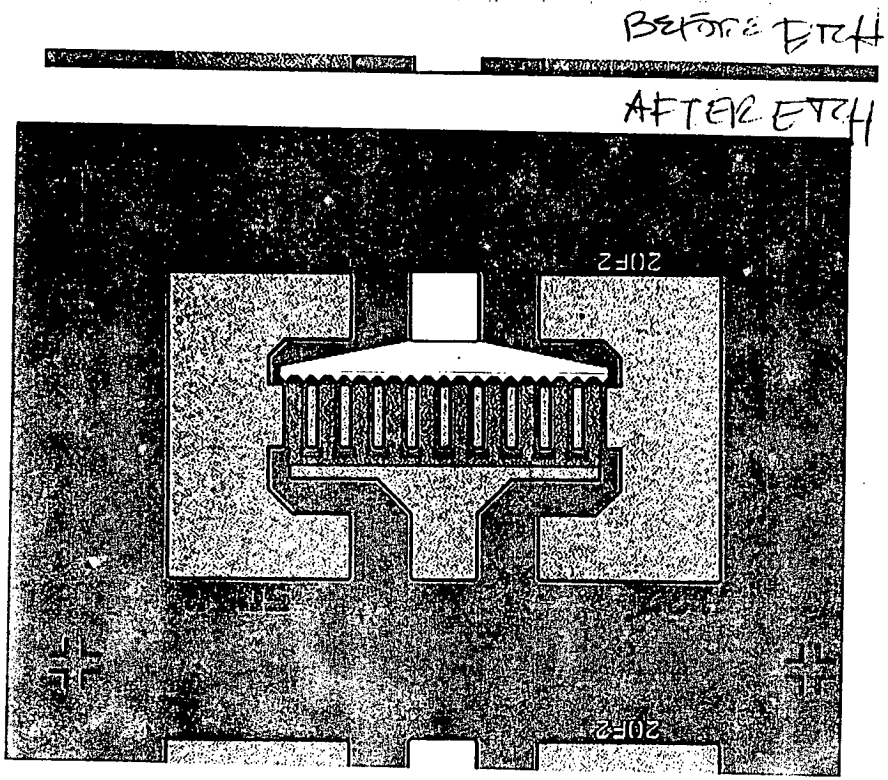


Rosanna

8/17/99

11:15

12:15



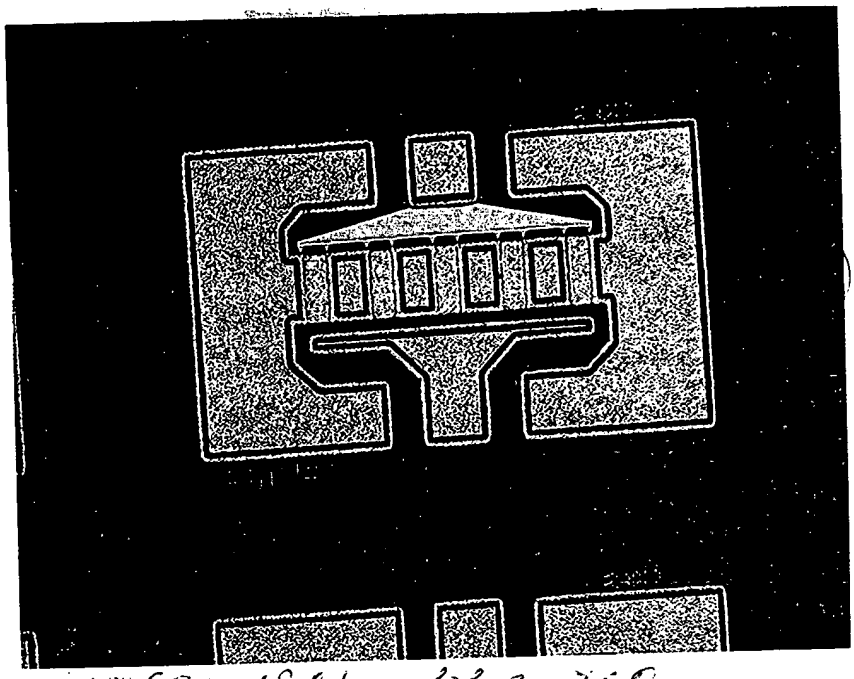
C/# BD9N364L Sample: WT990409A1

Rosanna: Please use ICP to etch 2-3 μm polyimide (PI) from inside pattern area (X) marked where end point

Left 15

FOR Roxanna
STEVE T

8/26/99



Frontside down

WT9904094A1 before ICP

C/# BDGN364L Sample WT9904094A1

Steve Roxanna: Pleas use ICP to etch Polyside (PT) from the field area ⊗ marked where end point can be used.

Typical 10–11 cycles, with 2–3 min overetch, total time 10–11 min.

Thanks. Please call x5743 when done & put in "OUT BOX".

Danny

ICP has been shut down

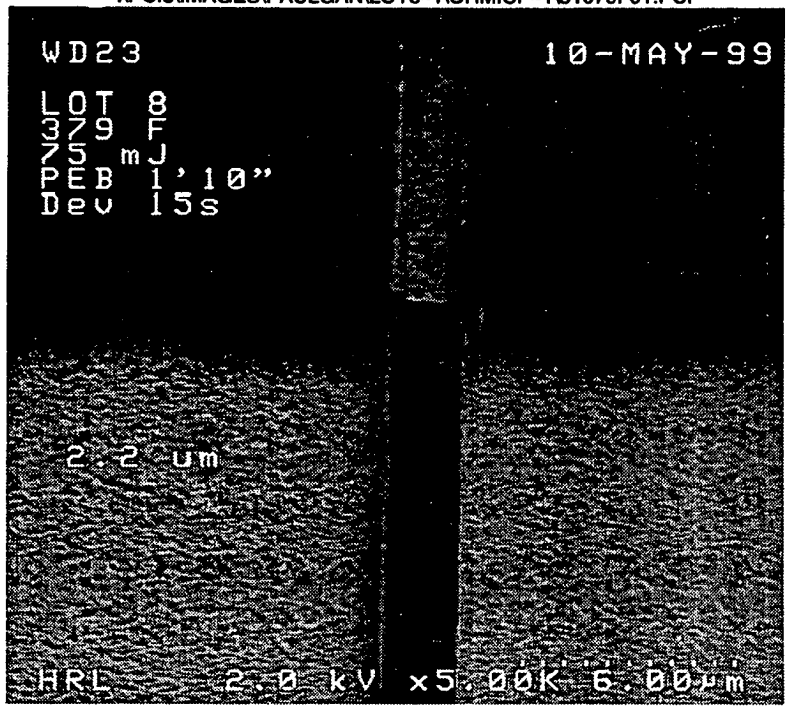
ICP: Run # 2129
10 per. 11'23"

8/25/99

179749

TEXAMPEL, UPPER SADDLE RIVER, NJ

.\PCI3\IMAGES\PAULGAN\LOT8~1\OHMICP~1\51079F01.PCI

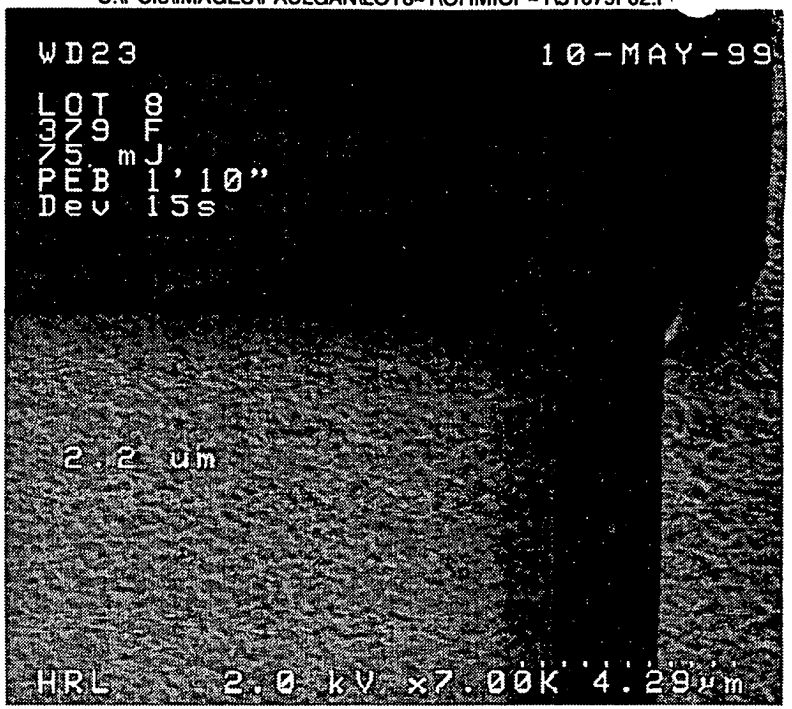


75 mj w/ hard contact

profile too re-entrant

contact not uniform

C:\PCI3\IMAGES\PAULGAN\LOT8~1\OHMICP~1\51079F02.P



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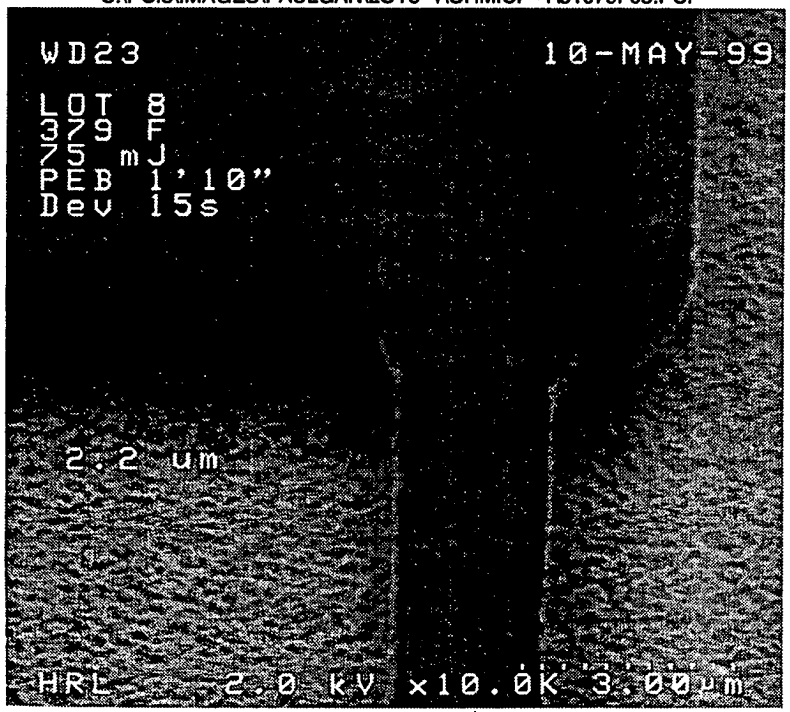

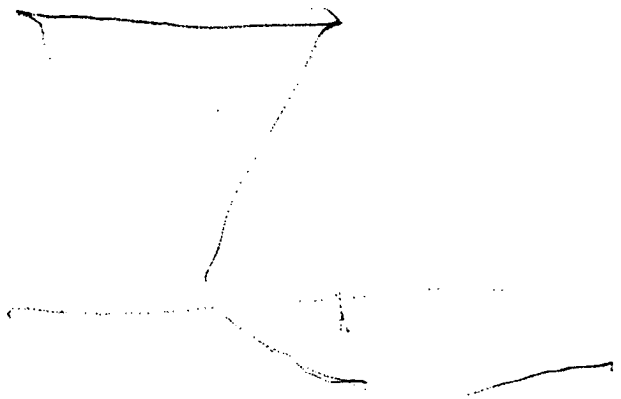

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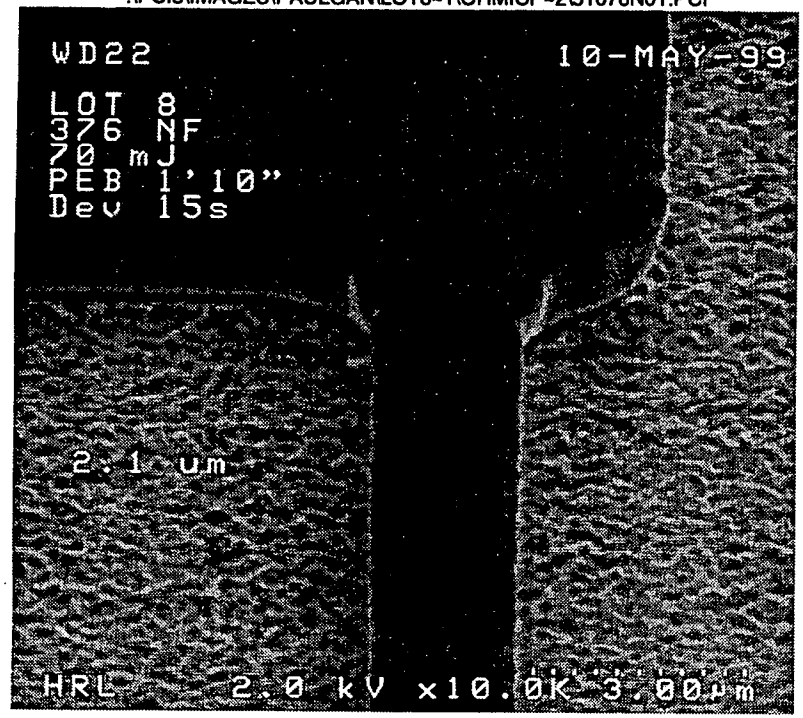
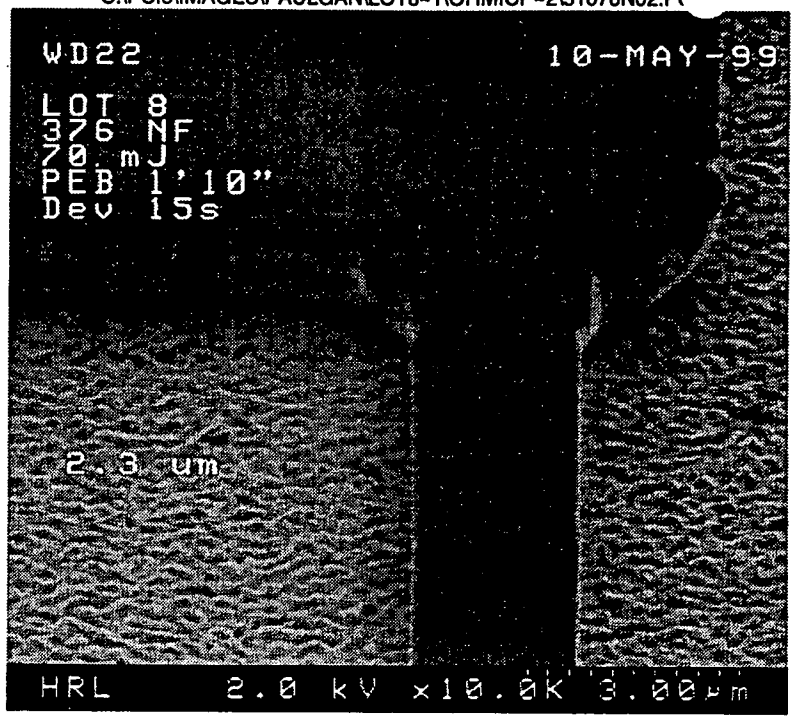


70 mJ
contact
= softer

- still profile non-reentrat

contact not uniform

C:\PCI3\IMAGES\PAULGAN\LOT8~1\OHMICP~2\51076N02.PC



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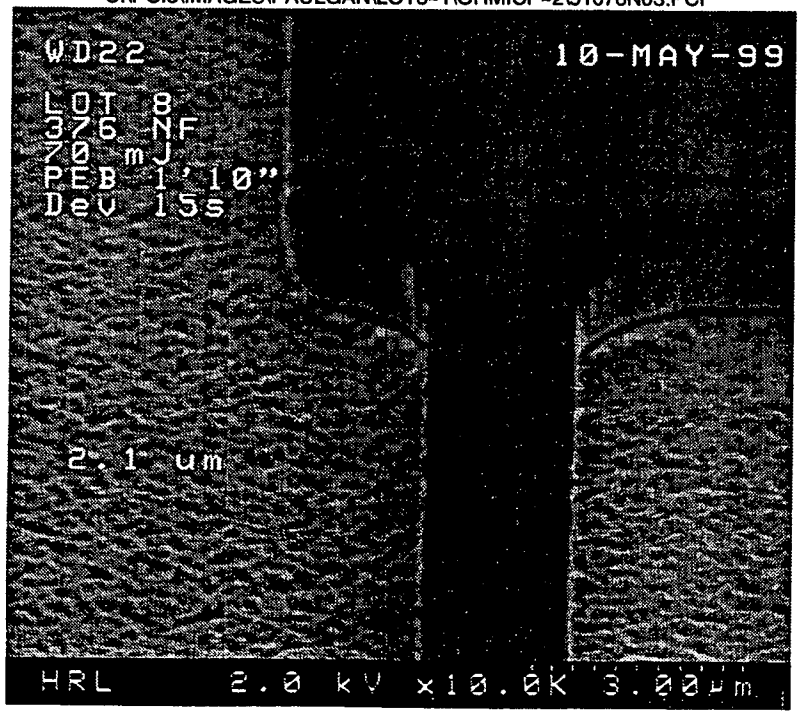

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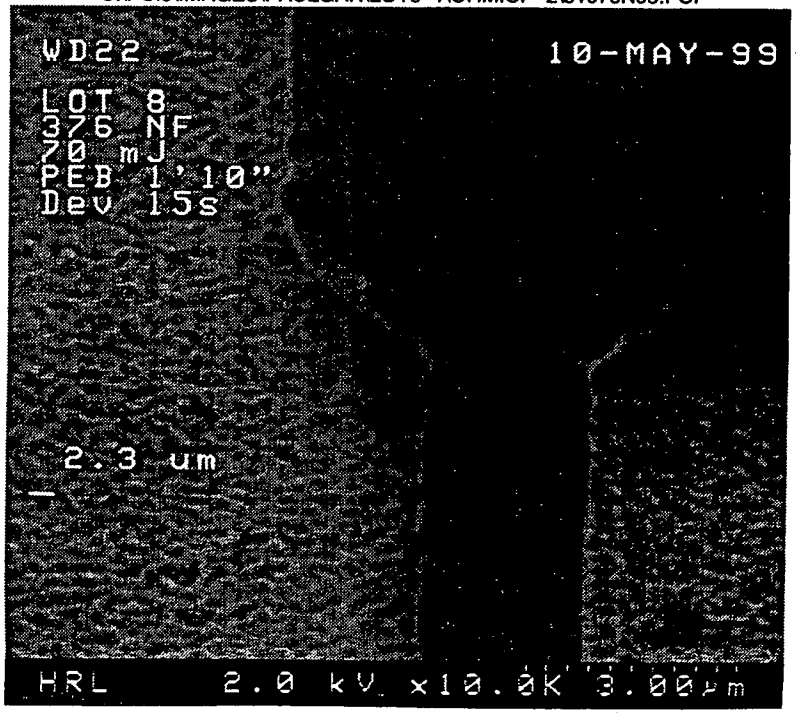

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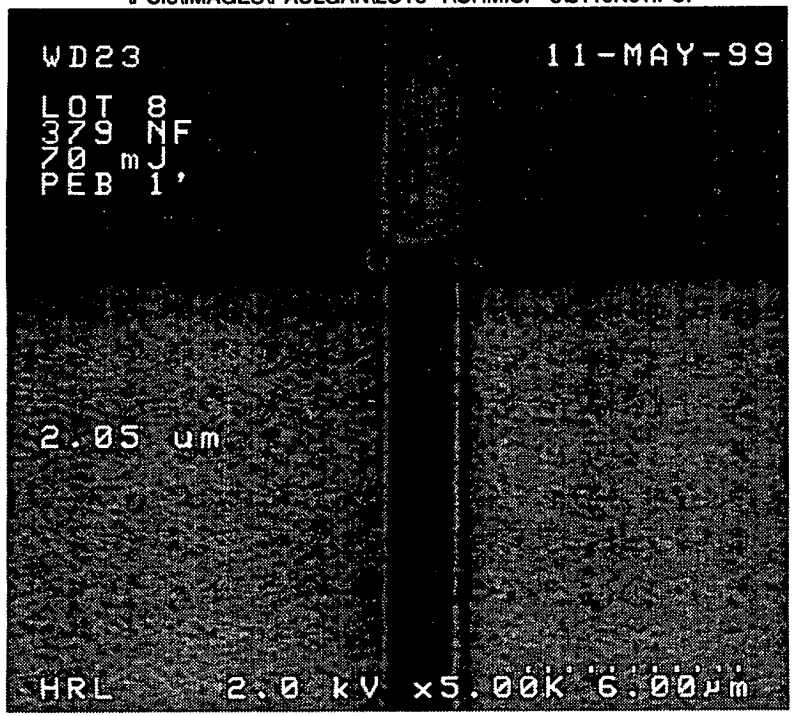


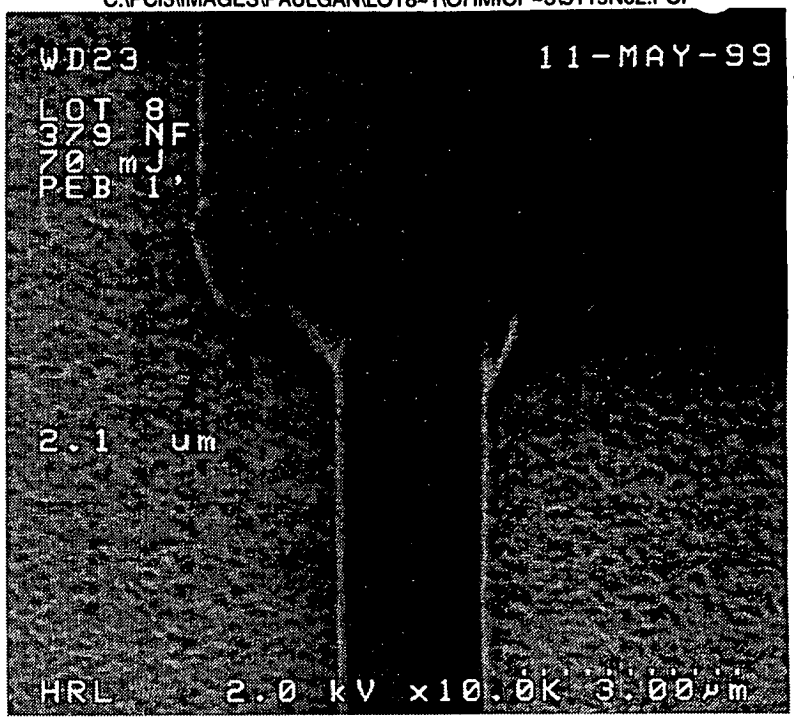
5-11-19

379 NF

70 mJ

PEB = 1'

C:\PCI3\IMAGES\PAULGAN\LOT8~1\OHMICP~3\5119N02.PCI



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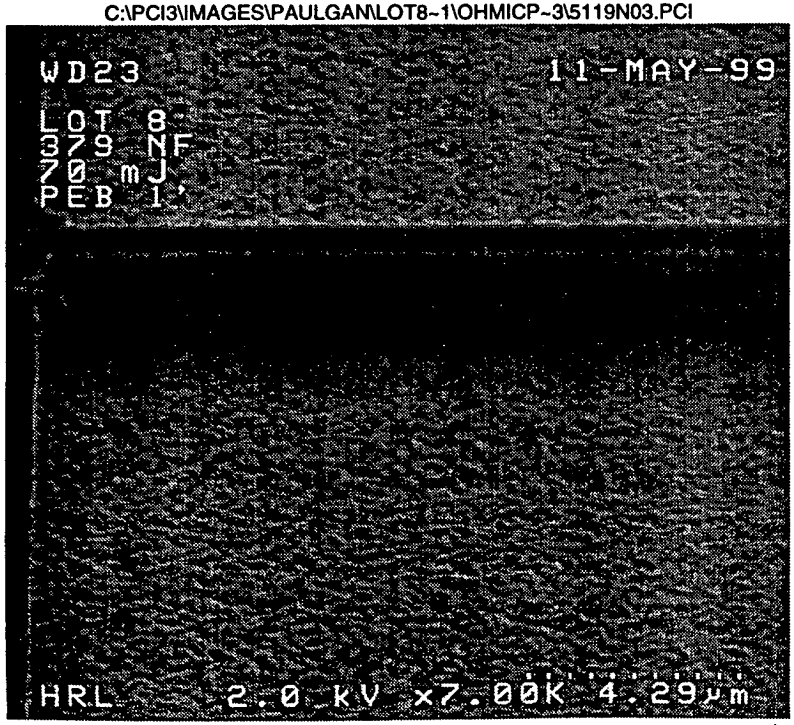
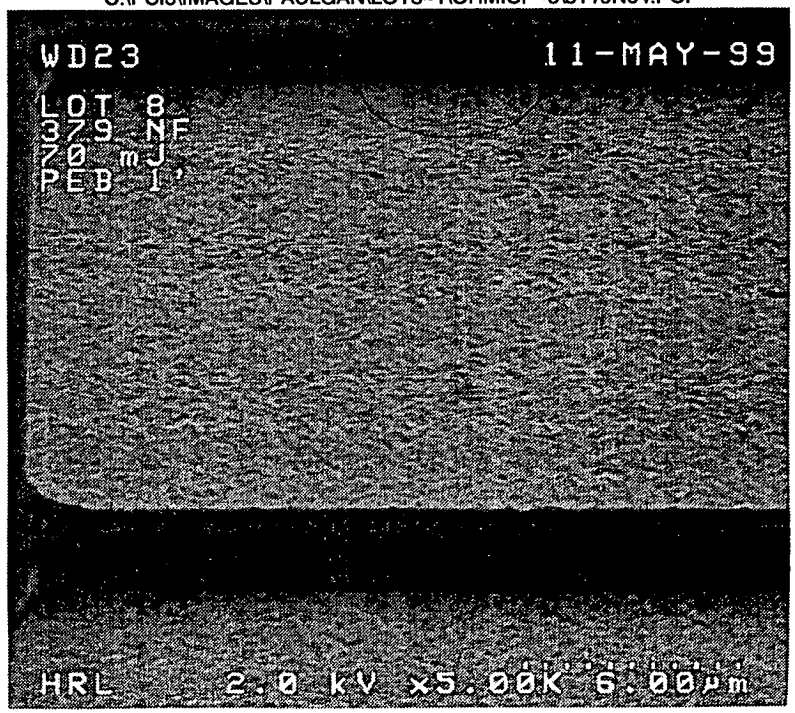


trace scalloping one area small

C:\PCI3\IMAGES\PAULGAN\LOT8~1\OHMICP~3\5119N04.PCI



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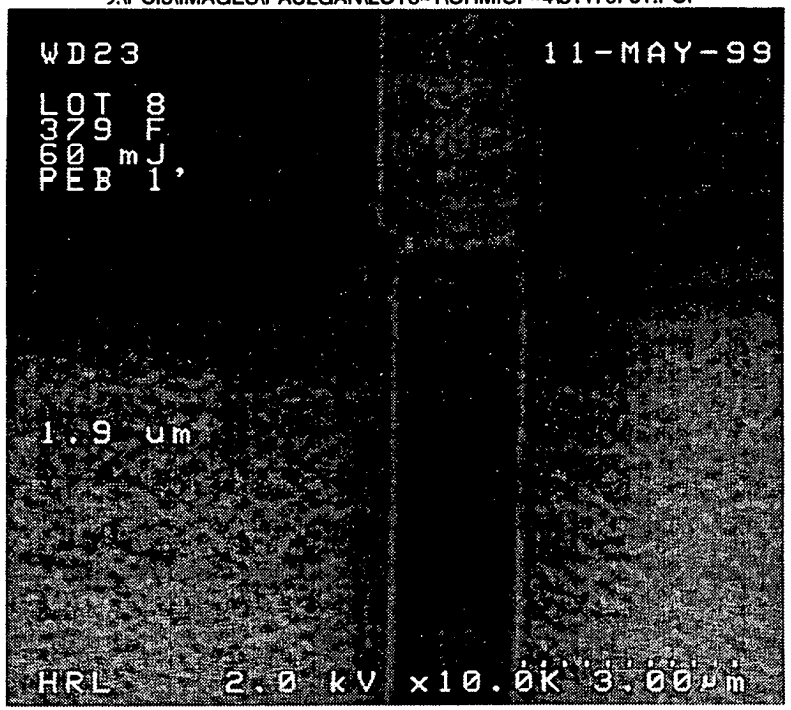
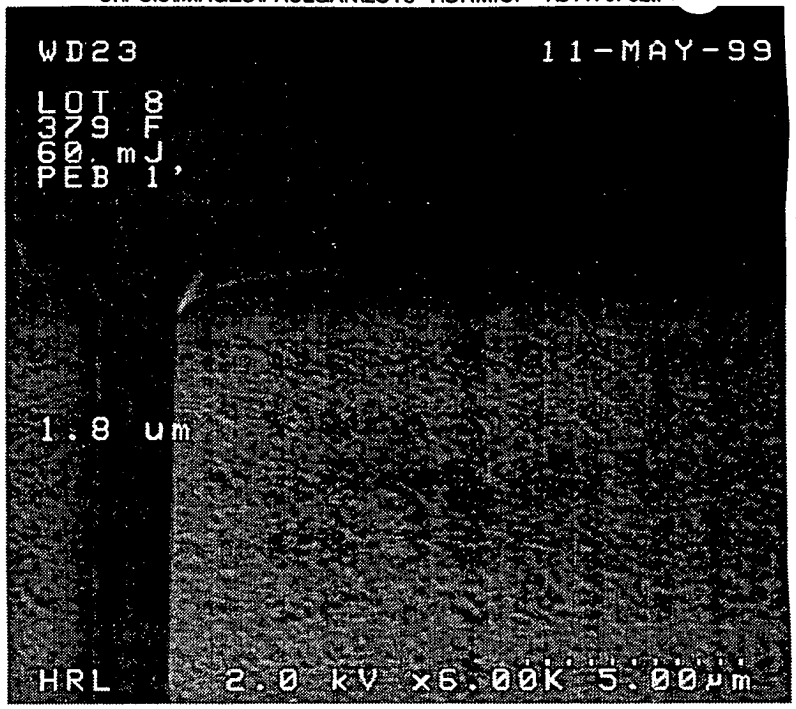


379 F
60 mJ,
PEB 1,

C:\PCI3\IMAGES\PAULGAN\LOT8~1\OHMICP~4\51179F02.P\



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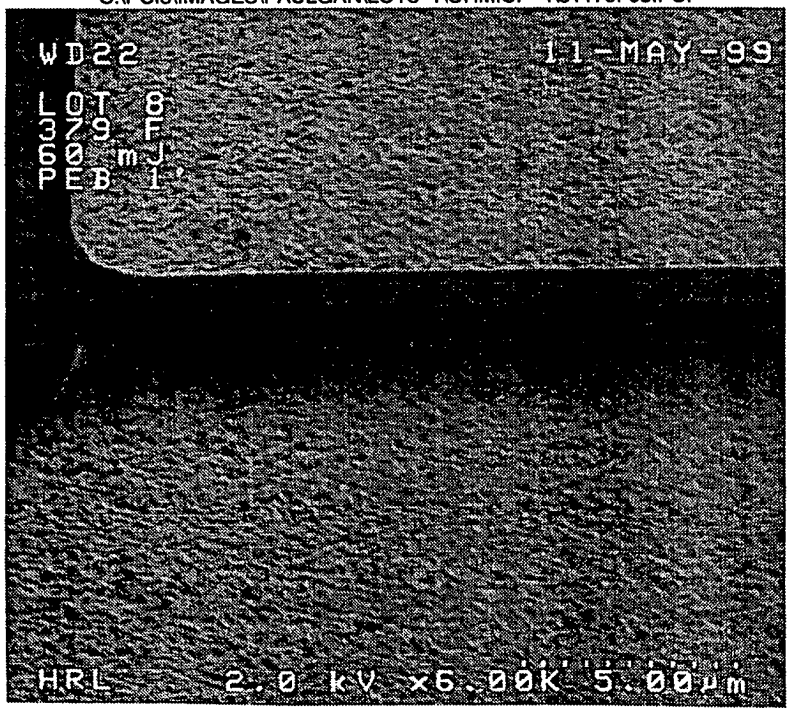

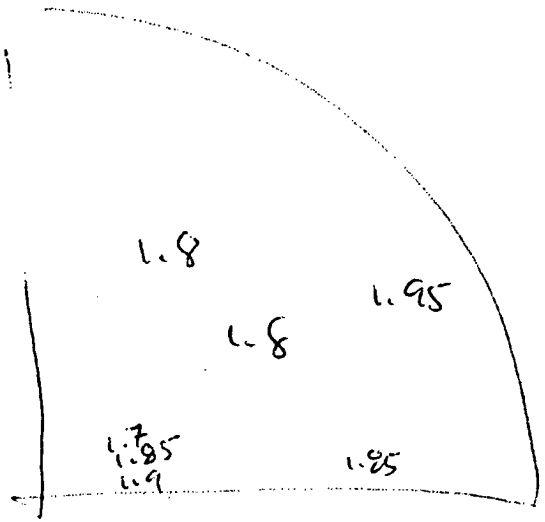

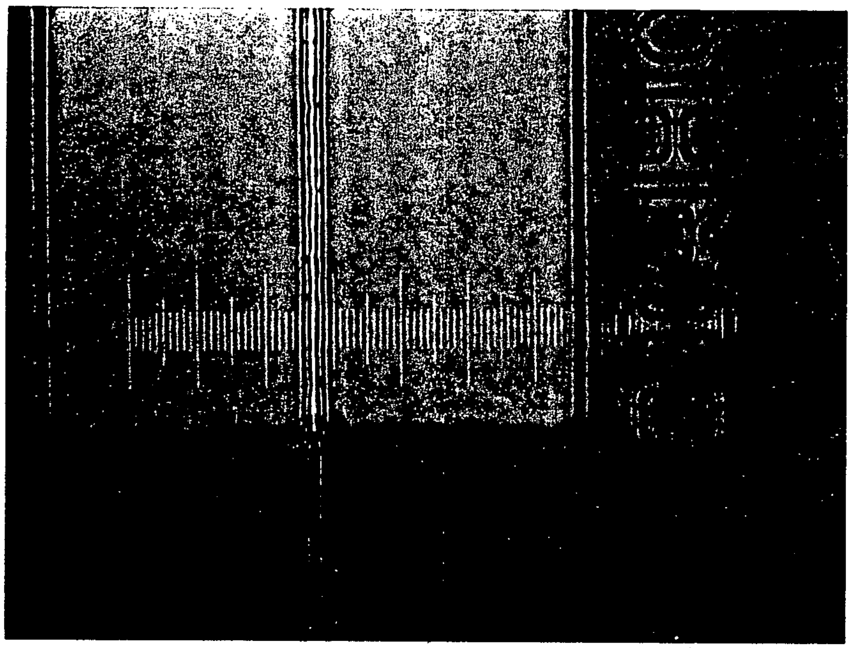

[illegible]

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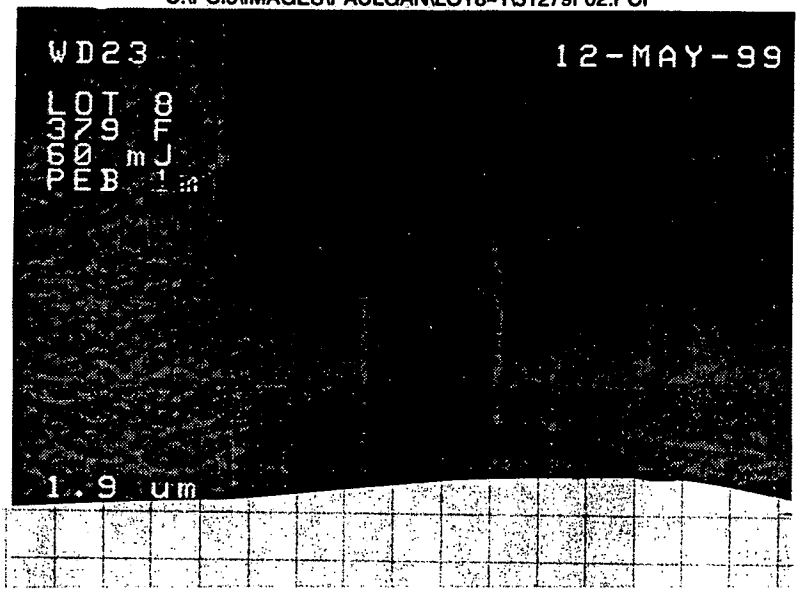

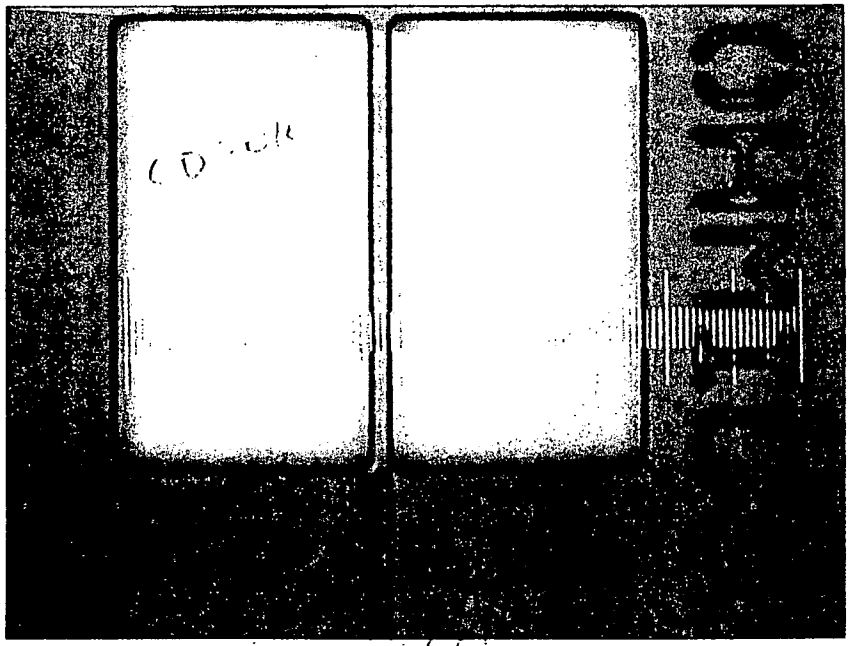

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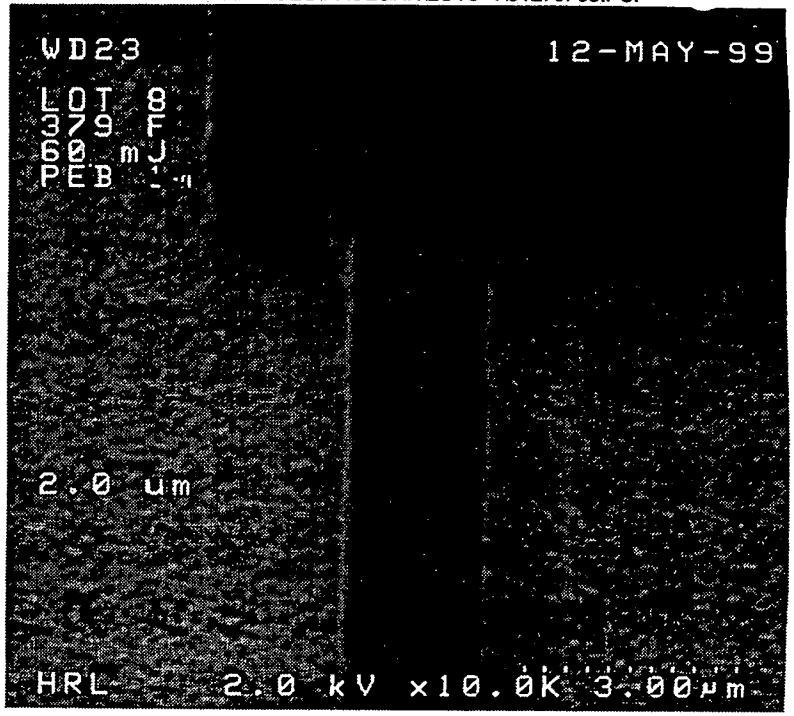
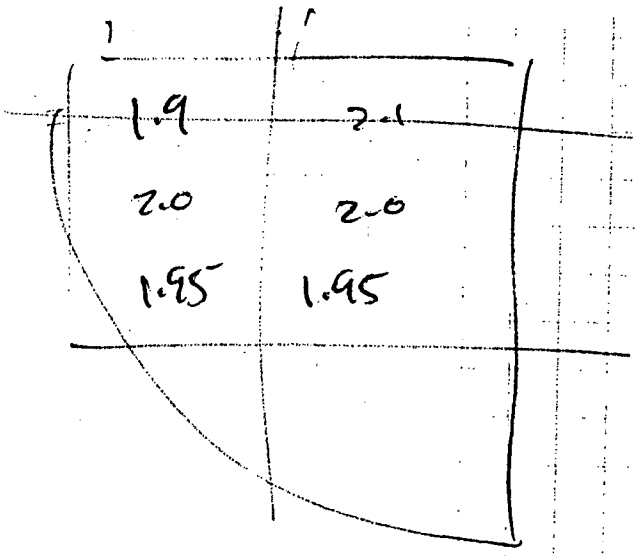
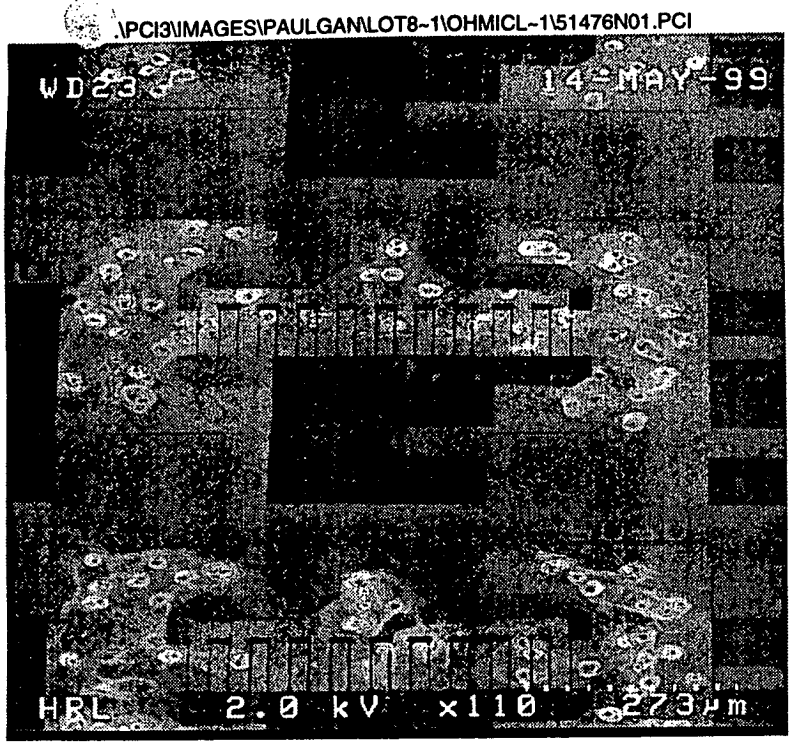
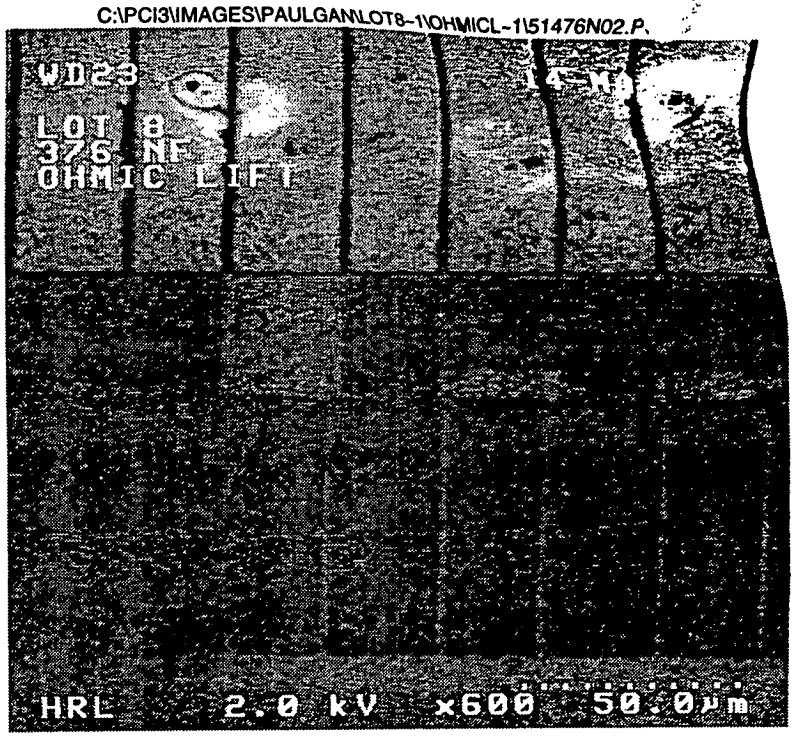
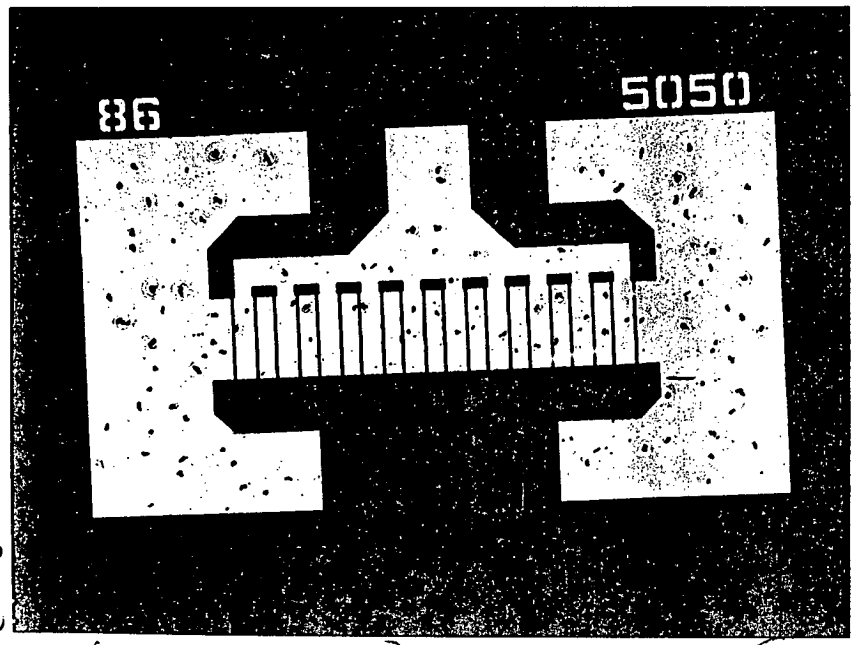




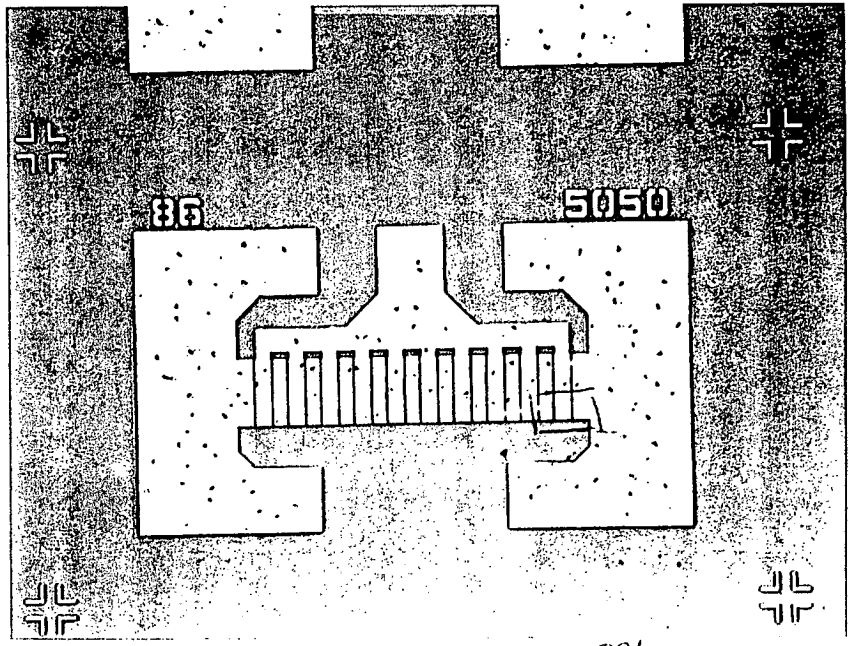






Lots split

After 20min PR strip ICP



Lot # 376 NF Pulse PRS

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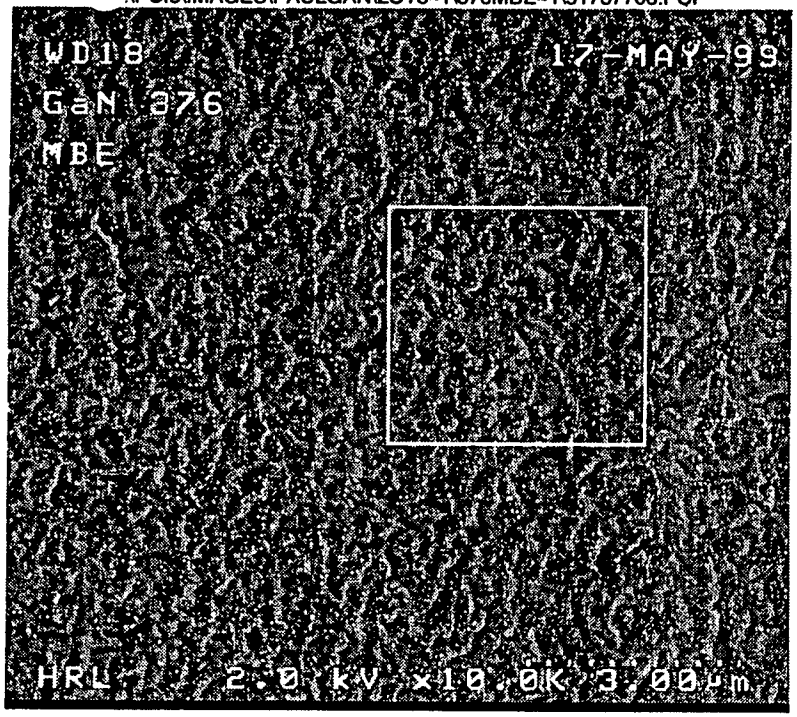
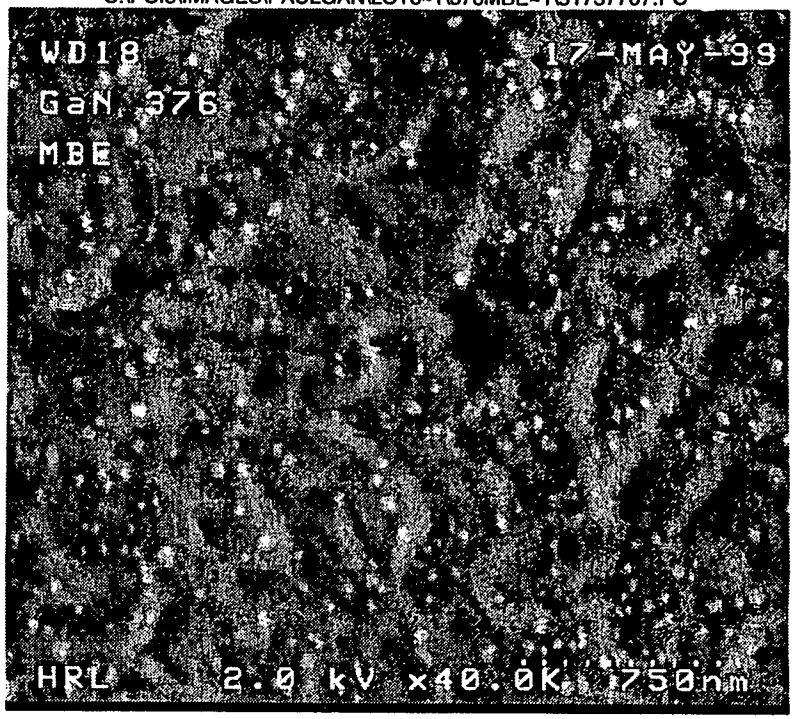


376
more
residue

C:\PCI3\IMAGES\PAULGAN\LOT8~1\376MBE~1\51737707.PC



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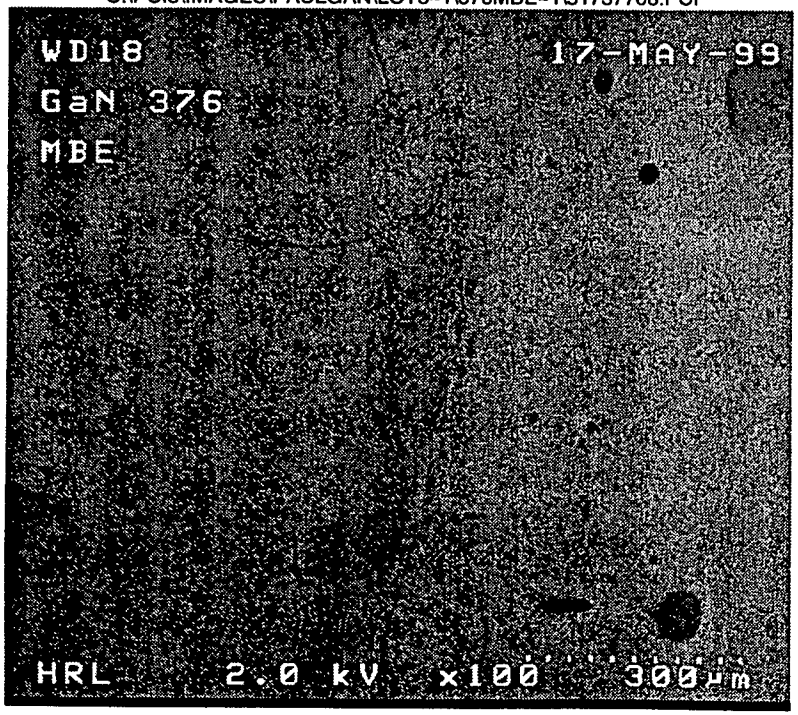

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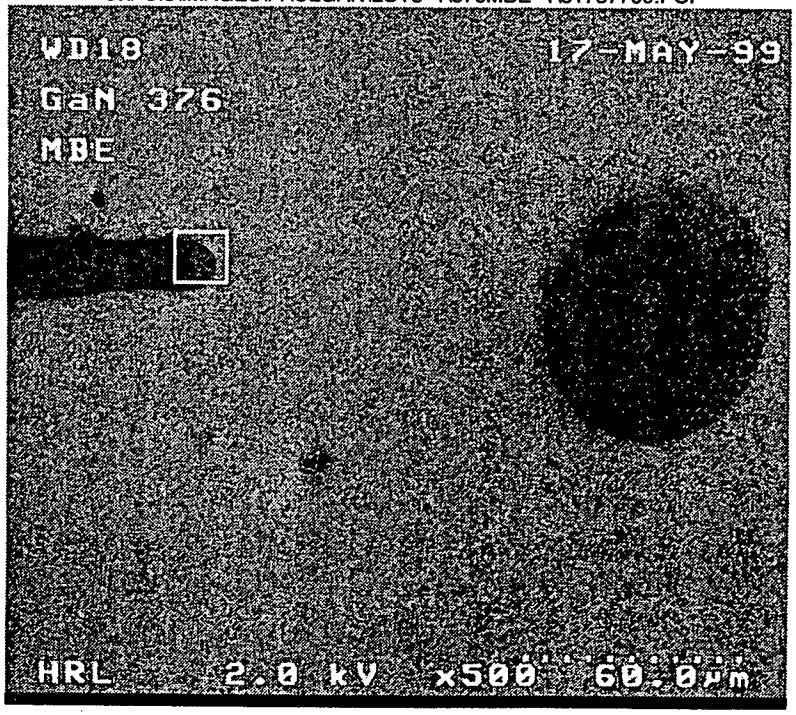

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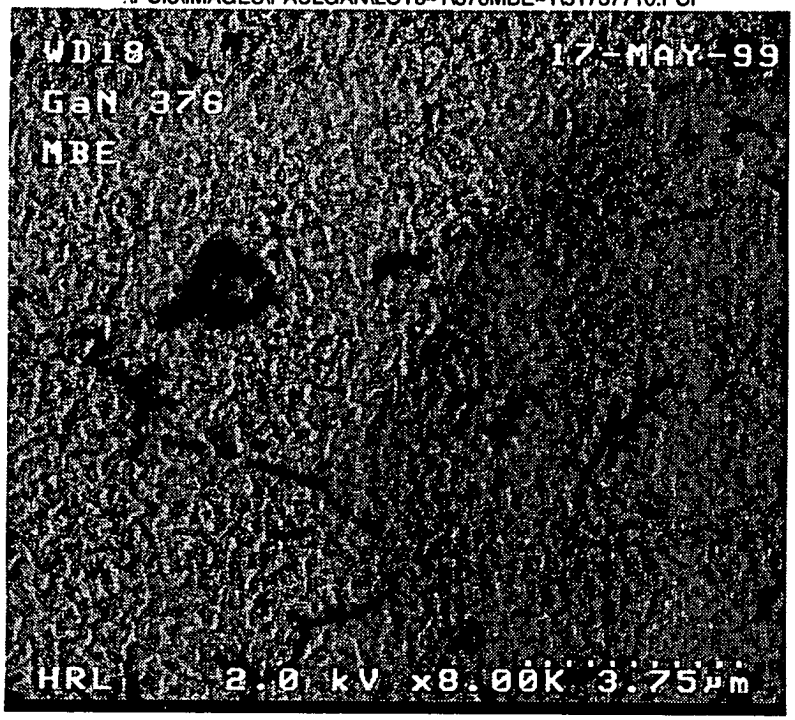

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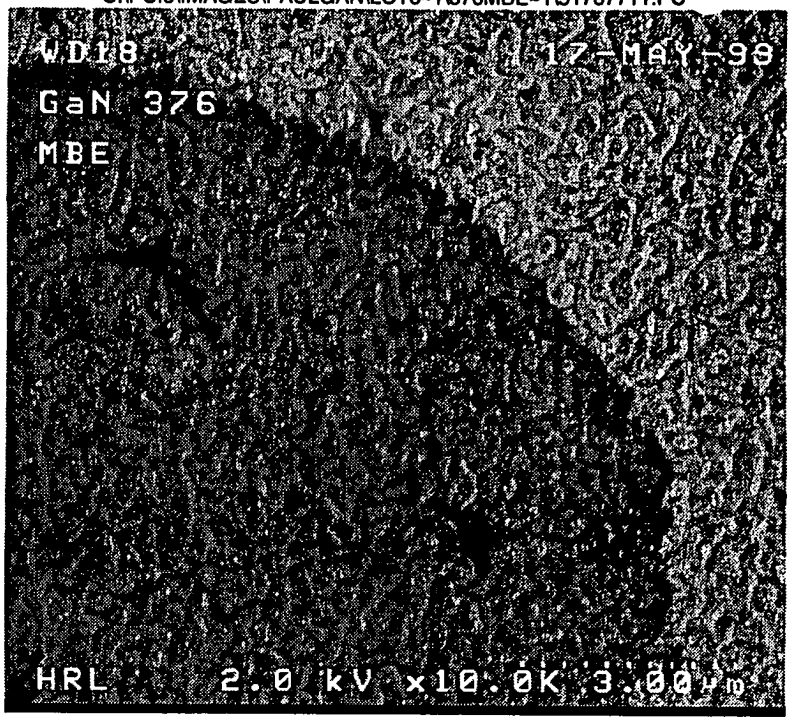

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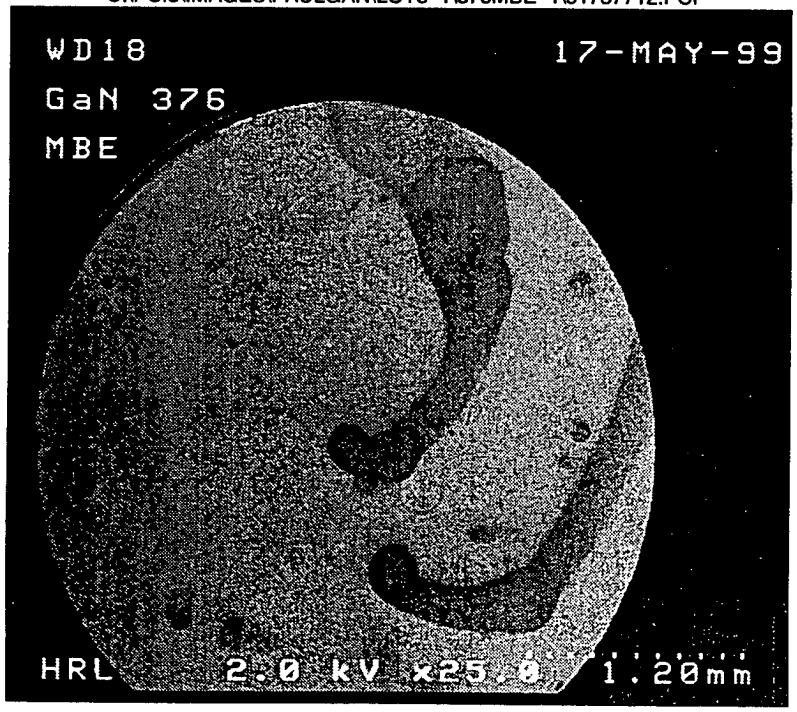

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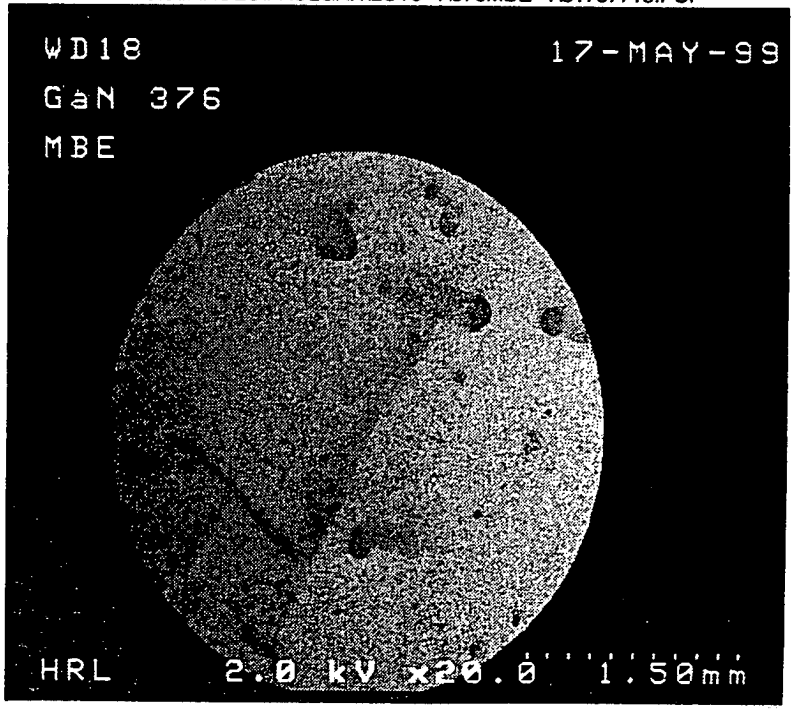

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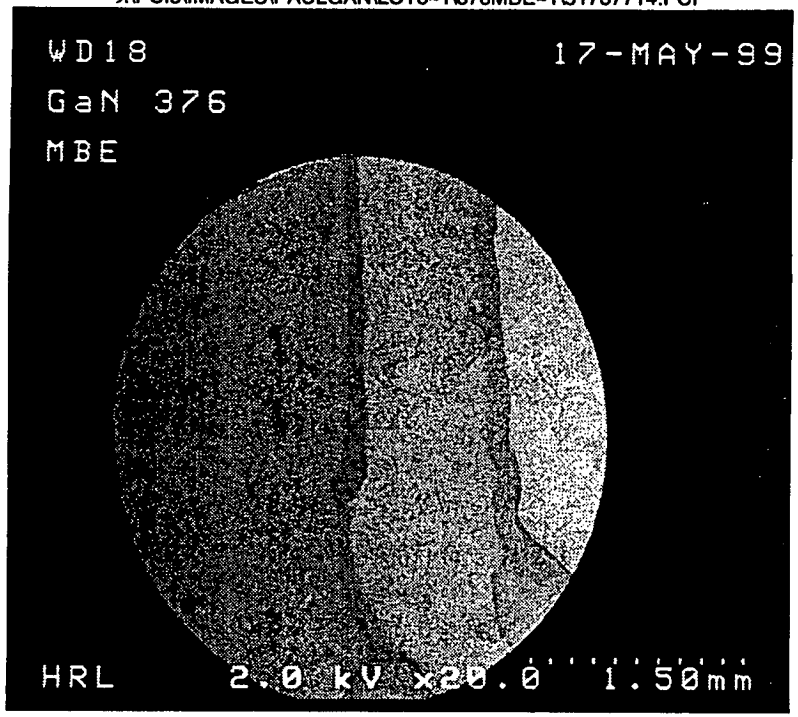

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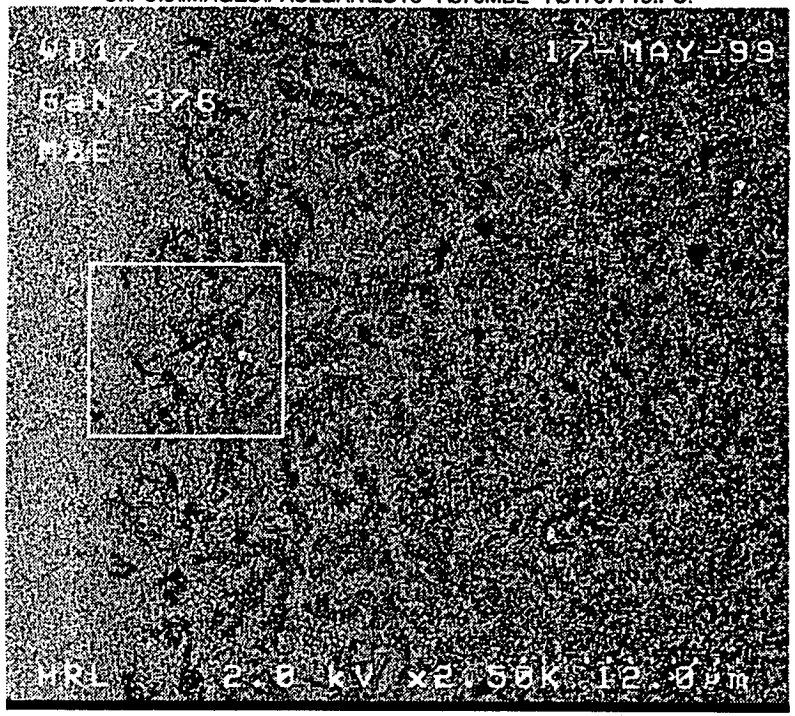

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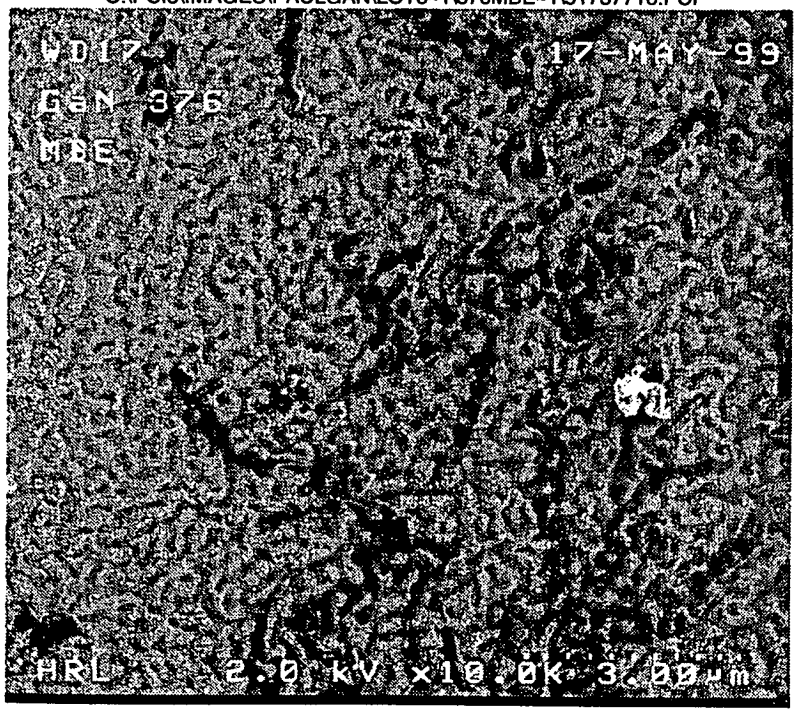

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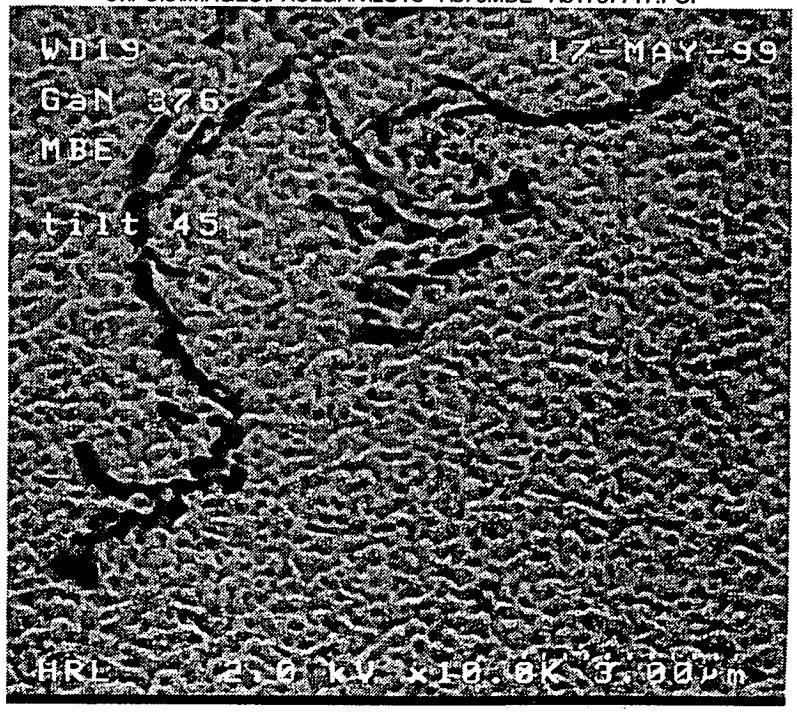

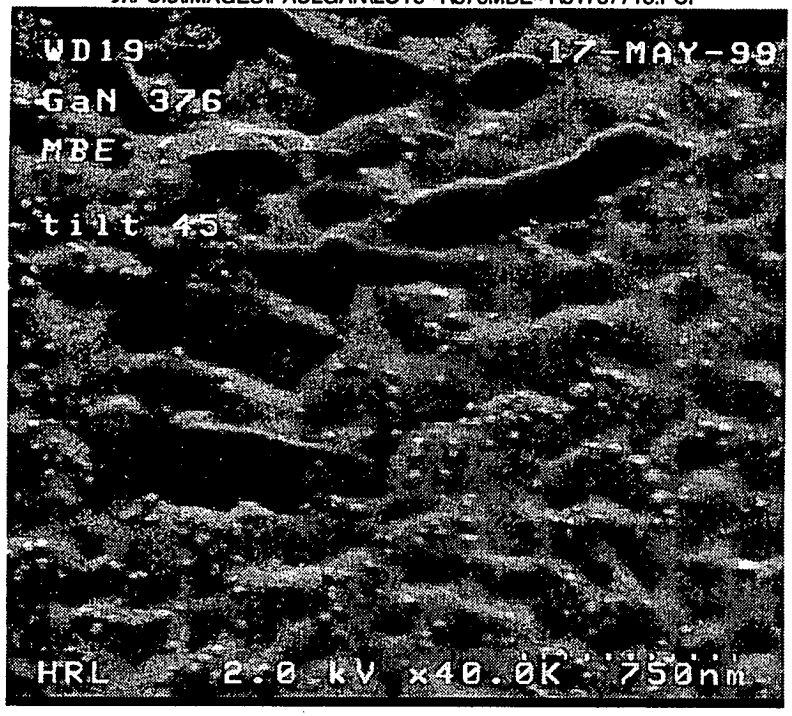
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GaN 376
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tilt 45
HRL
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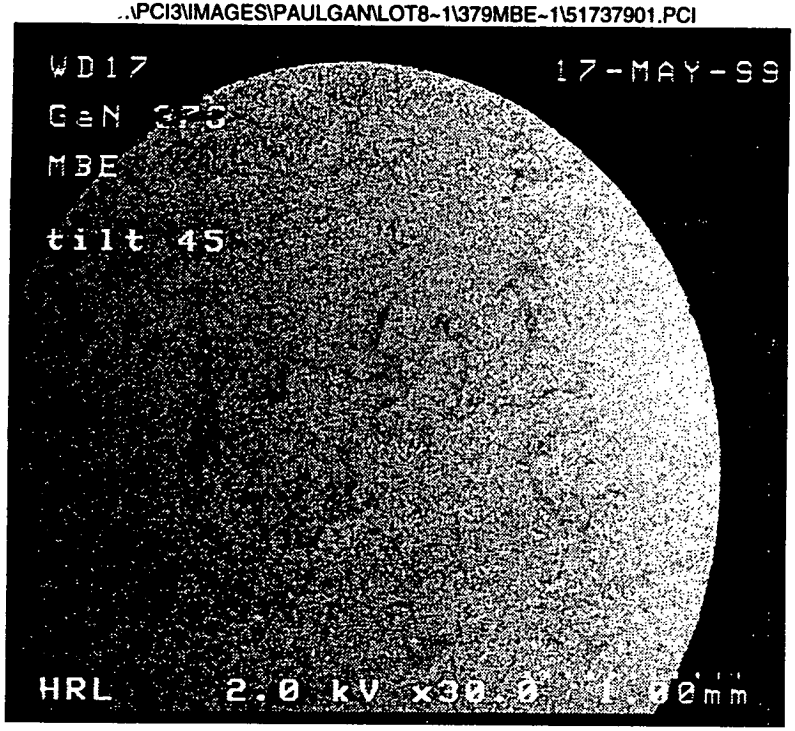

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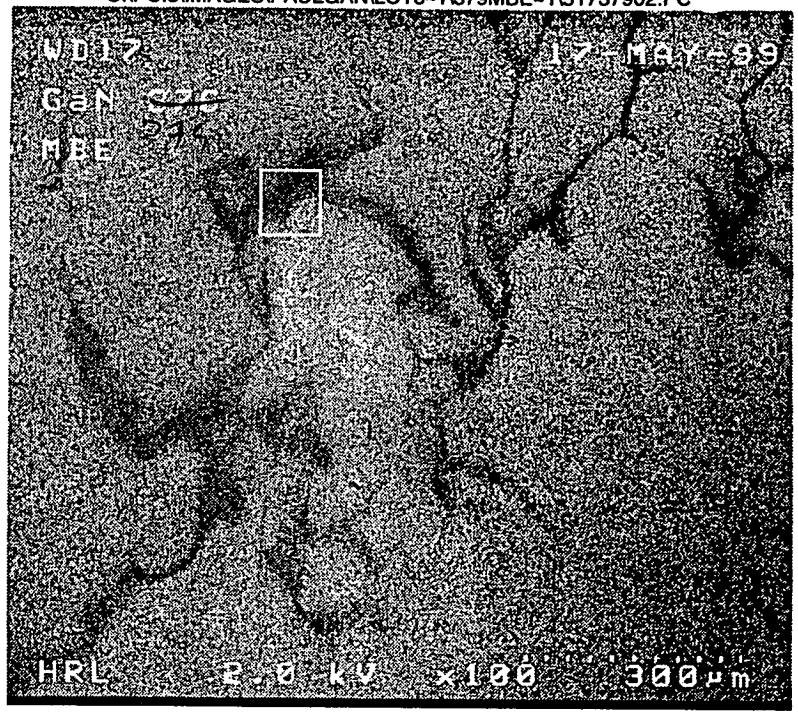

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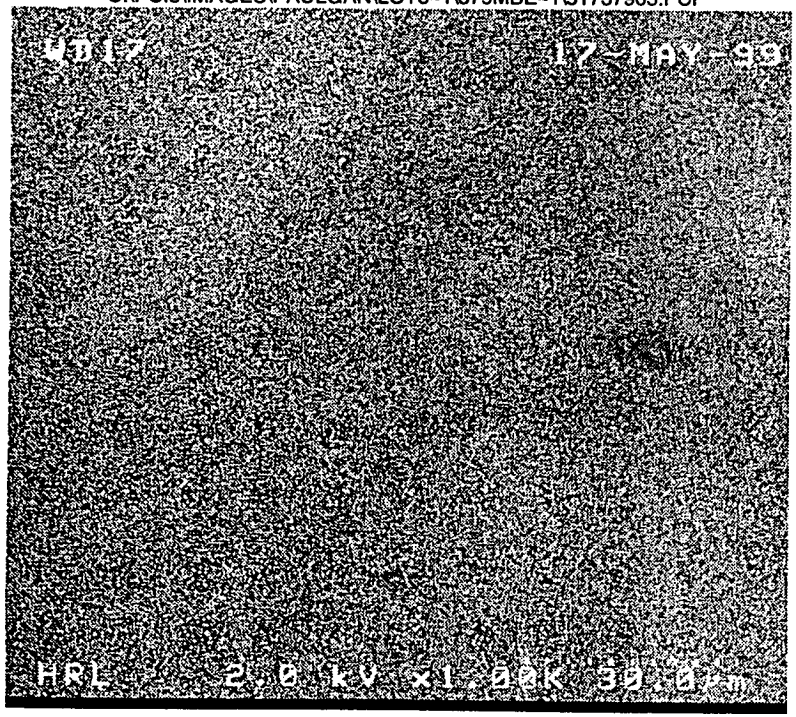

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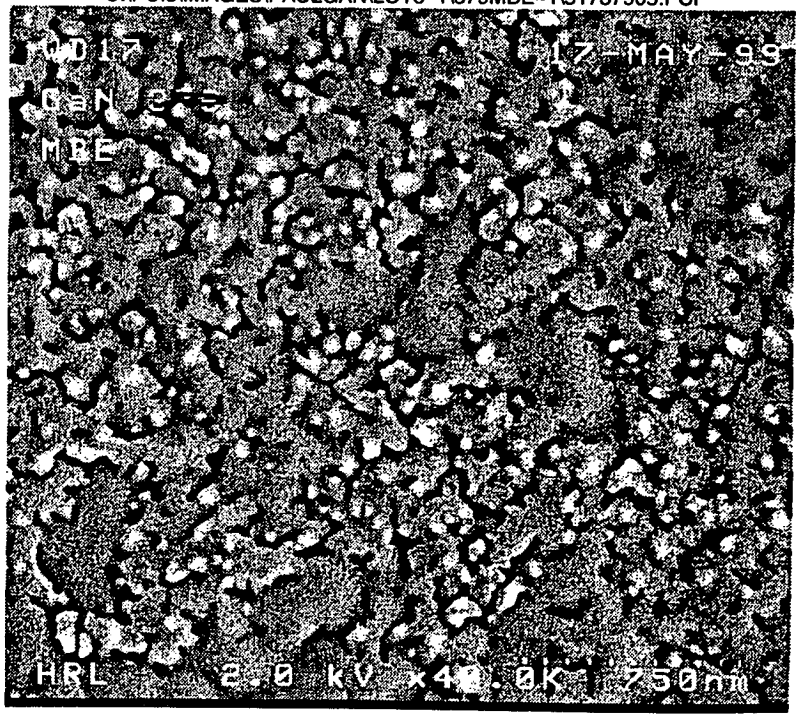

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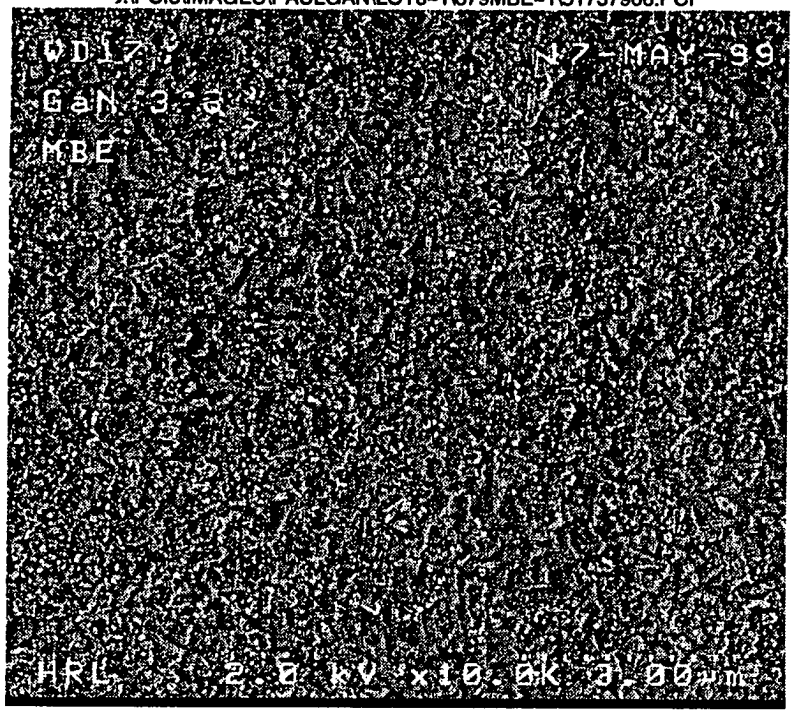

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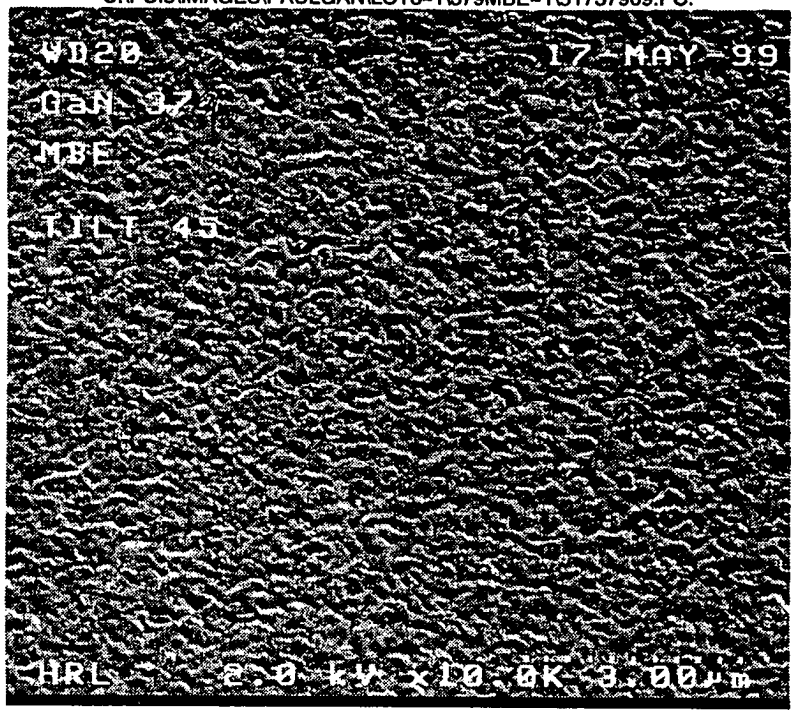

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